KNIGHT'S Forensic Pathology

Fourth Edition

Pekka Saukko | Bernard Knight

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KNIGHT's
Forensic Pathology

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Fourth Edition

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Those who have dissected or inspected many bodies have at least learned to doubt, while those who are ignorant of anatomy and do not take the trouble to attend to it, are in no doubt at all.

Giovanni Battista Morgagni 1682–1771
The Father of Morbid Anatomy

Taceant colloquia. Effugiat risus. Hic locus est ubi mors gaudet succurrere vitae.
(Let conversation cease. Let laughter flee. This is the place where death delights to help the living.)

Latin proverb

Seldom say never – seldom say always!

Forensic proverb

Notes on the cover design

Title of work: Illustrated Hand Scroll of the Poem of the Nine Stages of a Decaying Corpse (Kusoshi emaki)
Date: fourteenth century
Medium: scroll painting
Photographed by Shin'ichi Yamazaki
In the collection owned by: Kyushu National Museum, Dazaifu, Japan

This illustrated handscroll of 'The Poem of the Nine Stages of a Decaying Corpse' – an anatomically precise depiction of a female corpse in the various stages of decomposition – represents one of the earliest examples of this artform executed in Japan over a period of several centuries.

Its origins can be traced back to teachings of old Indian Buddhist sutras from the early fifth century promoting systematic meditation on the impurity of a decaying corpse as a means to conquer carnal desires and achieve enlightenment.

In general context, it can be understood as a symbol of the impermanence of human life, which a forensic pathologist in particular encounters in his daily work.

In scholarly context, it can be associated with other forensic pathological connotations: factual representation of the process of decomposition of the human body (shown in chronological sequence on the back cover) starting from the aspect of recent death, and proceeding through the various stages of putrefaction such as discoloration, bloating, destruction of the soft tissues by maggots, animal predation, skeletalization and complete disintegration of the body.

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Preface

Professor Bernard Knight wrote the first edition of this textbook based on his decades-long experience as a full-time forensic pathologist, consultant pathologist to the Home Office in the United Kingdom, academic teacher and author of several textbooks on forensic pathology and legal medicine. The first edition was published in 1990 followed by the second edition in 1996. The second edition of *Forensic Pathology* consolidated the international reputation of the original book as one of the foremost manuals of forensic pathology in the English language. After the second edition Professor Knight transferred the editorship to Professor Pekka Saukko, and the third edition was the product of collaboration with the original author and was published under the title of *Knight's Forensic Pathology* in 2004. This fourth volume follows the same concept. The text has undergone a complete revision to update where necessary, and 200 new colour illustrations have been added, replacing many of the old monochrome illustrations. This book uses photographs only where a relevant point is displayed, with a full caption that stands alone without having to refer to the text. Many line drawings are used, as the authors feel that they often get the message across better than a photograph, which of necessity contains irrelevant and perhaps distracting features. All the black and white drawings have been redrawn in full colour.

Many textual citations not listed in the previous edition have been added. However, the literature is now so vast (more than 1,000 forensic pathology-related papers, and around 4,000 in its sister discipline forensic science, are published annually in forensic and other specialist journals) that it is futile to try to capture all of even the most seminal papers. To give perspective and to remind us that our present scientific knowledge rests largely on the shoulders of earlier generations, historical references have also been included where appropriate. The interpretation of autopsy findings and many of the principles of morbid anatomy founded in the nineteenth century and earlier are still valid. The value of a publication is in its content, not in its date, as Harvey's *De Motu Cordis* and Morgagni's *De Sedibus* clearly demonstrate! Some of the most valuable papers in forensic pathology were written decades or even a century ago; the critical writings of Moritz, Shapiro, Adelson, Helpern, Gonzales, Polson – right back to Taylor and Tardieu in the nineteenth century – are examples of careful observation and logical thinking, which some modern pathologists, given to over-interpretation, would benefit from studying.

This is a textbook of forensic pathology, not forensic medicine. Though there is a considerable overlap, forensic medicine includes medical jurisprudence, the legal aspects of medical practice and many ethical matters, none of which are found – nor are intended to be found – in these pages. Such topics have marked geographical limitations, as a result of legal, ethnic, cultural and even religious variations from place to place. The subject matter of this volume is solely concerned with the examination of the dead body for medico-legal purposes. Even in this limited sphere, police procedures and the habits of pathologists will vary considerably with country and with resources, but it is hoped that the routines, techniques and philosophy offered in this book will offer a guide to good practice that can then be modified according to local circumstances.

The contents are intended to lead the pathologist – and in some countries, the non-pathologist – through the procedures that are needed in the examination of a body found under obscure, suspicious or frankly criminal circumstances. In developed countries with sophisticated medico-legal systems, such autopsies will be performed only by forensic pathologists or by histopathologists with considerable experience, but in many areas of the world – especially the developing countries – lack of manpower and resources as well as considerations of distance and facilities mean that almost any doctor may be called upon to perform medico-legal examinations. For both of these classes of medical men and women this book aims to act as a guide and a source of reference. Where the pronoun 'he' is used throughout this book, it is intended that the word 'she' is equally applicable, unless obviously inappropriate from the context.

The subject matter follows a fairly conventional pattern, but the treatment of each topic is designed to offer practical advice linked with a philosophical approach that leads the doctor to analyse and question the interpretations drawn from physical findings. All too often, dogmatic opinions are derived from an unsound factual base, learned from lectures or textbooks that repeat previous dogma with little sense of critical evaluation. In some parts of the world forensic pathology is learned by rote from teachers who studied it themselves in the same fashion, and who have little or no practical experience in the hard schools of mortuary or witness-box. We hope that this book will at least stimulate trainee forensic pathologists to think twice, question and disagree.

Pekka Saukko
Bernard Knight

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P.S. & B.K.

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Abbreviations

ABFO American Board of Forensic Odontology
ADD accumulated degree day
ADP adenosine diphosphate
AER alcohol elimination rate
AF acid fuchsin
AFE amniotic fluid embolism
AHA American Heart Association
AHT abusive head trauma
AI axonal injury
AIDS acquired immunodeficiency syndrome
AIS Abbreviated Injury Scale
APP amyloid precursor protein
ARVC arrhythmogenic right ventricular cardiomyopathy
ATP adenosine triphosphate
AV atrio-ventricular
AVM arteriovenous malformation
βAPP β-amyloid precursor protein
BAC blood-alcohol content
BBB blood–brain barrier
BMI body mass index
BP before period
BSAC British Sub-Aqua Club
BZP benzylpiperazine
CDC Centers for Disease Control and Prevention
CEMD Confidential Enquiry into Maternal Deaths
CFC chlorofluorocarbon
CHD coronary heart disease
CiRCA cardioinhibitary reflex cardiac arrest
CL chemiluminescence
CLSM confocal laser scanning microscopy
CMACE Centre for Maternal and Child Enquiries
CNS central nervous system
CO carbon monoxide
COM calcium oxalate monohydrate
CPR cardiopulmonary resuscitation
CSF cerebrospinal fluid
CSI crime scene investigator
CT computed tomography
D2PM diphenylprolinol
D&E dilatation and evacuation
DAI diffuse axonal injury
DAN Divers Alert Network
DCM dilated cardiomyopathy
DI dysbaric illness
DIC disseminated intravascular coagulation
DIMS Diving Incidence Monitoring Study
DNA deoxyribonucleic acid
DNOC dinitro-orthocresylphosphate
2-DPMP desoxypipradrol
DPR dermatopathia pigmentosa reticularis
DVT deep vein thrombosis
EA European Co-operation for Accreditation
ECG electrocardiogram
EDH extradural haemorrhage
ECLM European Council of Legal Medicine
EDTA ethylenediamine tetra-acetate
EDX energy dispersive X-ray microanalyser
ELISA enzyme-linked immunosorbent assay
ENFSI European Network of Forensic Science Institutes
FABP fatty acid binding protein
FDA Food and Drug Administration
FDCM familial dilated cardiomyopathy
FISH fluorescent *in situ* hybridization
GBL gamma-butyrolactone
GC-MS gas chromatography-mass spectrometry
GCS Glasgow Coma Scale
GINA Global Initiative for Asthma
GSR gunshot residues
GTN glyceryl trinitrate
H&E haematoxylin and eosin
HbCO carboxyhaemoglobin
HBFP haematoxylin/basic fuchsin/picric acid
HCM hypertrophic cardiomyopathy
HETP hexaethyltetraphosphate
HIV human immunodeficiency virus
H-MRS proton magnetic resonance spectroscopy
ICP intracranial pressure
IDCM idiopathic dilated cardiomyopathy
IEC International Electrotechnical Commission
IIH idiopathic intracranial hypertension
ILAC International Laboratory Accreditation Cooperation
INVM isolated non-compaction of the ventricular myocardium
ISO International Organization for Standardization

IVCT *in vitro* muscle contracture test
IVH intraventricular haemorrhage
IVRA intravenous regional anaesthesia
LAD left anterior descending
LFB luxol fast blue
LOC loss of consciousness
LOQ limit of quantification
LSCB Local Safeguarding Children Board
LSD lysergic acid diethylamide
LSS live skeletal survey
LUCAS Lund University Cardiac Arrest System
MDA methyl 3,4-methylenedioxyamphetamine
MDMA 3,4-methylenedioxymethamphetamine
MH malignant hyperthermia
MI myocardial infarction
miRNA micro ribonucleic acid
MMR maternal mortality ratio
MRI magnetic resonance imaging
MRSI magnetic resonance spectroscopic imaging
MSB Martius scarlet blue
MSCT multislice computed tomography
msw metres of sea water
mTBI mild traumatic brain injury
mtDNA mitochondrial deoxyribonucleic acid
NAA N-acetylaspartate
NAHI non-accidental head injury
NAI non-accidental injury
NFJS Naegeli–Franceschetti–Jadassohn syndrome
NICHD National Institute of Child Health and Human Development
NMR nuclear magnetic resonance
NSCLC non-small cell lung carcinoma
NSPCC National Society for the Prevention of Cruelty to Children
OC oleoresin capsicum
OFSTED Office for Standards in Education, Children's Services and Skills
OI osteogenesis imperfecta
OMPA octamethylpyrophosphamide
OP organophosphorus
PBT pulmonary barotrauma
PCP piperidine hydrochloride
PCR polymerase chain reaction
PCS post-concussive symptoms
PD Parkinson's disease
PDS Pokkuri death syndrome
PG prostaglandin
PICA posterior inferior cerebellar artery
PMCTA post-mortem computed tomography angiography
PMI post-mortem interval
PMN polymorphonuclear neutrophil
PMSS post-mortem skeletal survey
PSA prostate-specific antigen
PTAH phosphotungstic acid-haematoxylin
PVC polyvinylchloride
RCA right coronary artery
RIA radioimmunoassay
SA sino-atrial
SAH subarachnoid haemorrhage
SAP standardized autopsy protocol
SCLC small cell lung carcinoma
SCR Serious Case Review
SDH subdural haemorrhage
SEM scanning electron microscopy
SG semenogelin
SIADH syndrome of inappropriate antidiuretic hormone hypersecretion
SIB sacroiliac joint bridging
SIDS sudden infant death syndrome
SOCO scene of crime officer
SOP standard operating procedure
SS skeletal survey
STD sexually transmitted disease
STR short tandem repeat
SUDI sudden unexpected death in infancy
TAI traumatic axonal injury
TBSA total body surface area
TEPP tetraethylpyrophosphate
THC tetrahydrocannabinol (cannabis)
TSS toxic shock syndrome
UAC urine alcohol content
UV ultraviolet
VR volume rendering
WHO World Health Organization

CHAPTER 1

The Forensic Autopsy

- Types of autopsy
- Autopsy legislation, guidelines, standards
- The procedure for a forensic autopsy
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Though 'necropsy' is semantically the most accurate description of the investigative dissection of a dead body, the word 'autopsy' is used so extensively that there is now no ambiguity about its meaning.

The term 'post-mortem examination' is a common alternative, especially in Britain, where its meaning is never in doubt. Unfortunately, it suffers from a lack of precision about the extent of the examination, for in some countries many bodies are disposed of after external examination without dissection.

It is obvious that even in a primitive tribal society there must have been an interest in discovering the causes of death of its members. In particular, a sudden, unexepected or unwitnessed death must have signalled a potential danger, either from within the society by its own members or by an enemy from the outside.[1] Therefore, it is logical that, when societies started to develop and get more organized, the forensic investigation of deaths was introduced relatively early due to the requirements of the judicial system. The oldest known official instructions about the external investigation of corpses have been dated to the Ching-dynasty (~2000 BC) in ancient China. A decree enacted during the Song-dynasty (960–1279 AD), in 995 AD, provided that a government official had to investigate a violent or suspicious death within 4 hours and failure to do so was punishable.[2,3] The earliest known forensic dissections took place in Italy, probably in the middle of the thirteenth century, at the University of Bologna. One was recorded by Guglielmo de Placentinus Saliceto, or William of Saliceto (1210–1277), a surgeon and a teacher in the medical faculty there. In his book *Surgery* he mentioned a case examined in about 1275.[4] It is, however, uncertain whether this was an autopsy or just an external examination of the body. Possibly the first reliable record of a medico-legal autopsy in those days has been attributed to Bartolomeo da Varignana, a professor of medicine, who served the municipality of Bologna in a medico-legal capacity. The public prosecutor had ordered an autopsy in the suspected poisoning of a nobleman, Azzolino, in February 1302. The autopsy was performed by two physicians and three surgeons under the leadership of da Varignana.[2,5,6]

The principles of the modern medico-legal investigation were developed based on the codes of the sixteenth century Europe: the Bamberg Code in 1507, the Caroline Code in 1532 and later the Theresian Code in 1769. Further development of the medico-legal autopsy has been greatly influenced by the judicial system adopted, the main emphasis in most countries being in the detection and investigation of criminal and other unnatural or unexpected deaths.

In the course of the following centuries autopsies were increasingly performed and recorded, contributing to the advancement of pathology. The hospital or clinical autopsy became meaningful after the introduction of improved autopsy methods by Carl von Rokitansky (1804–1878) and Rudolf Virchow (1821–1902) and by modern concepts of the pathogenesis of disease, in particular, cellular pathology introduced by Virchow.[7]

Types of autopsy

Though medical conventions and legal systems vary considerably from country to country, there are generally two main types of autopsy:

- The *clinical* or *academic autopsy* is one in which the medical attendants, with the consent of relatives, seek to learn the extent of the disease for which they were treating the deceased patient. In most jurisdictions this type of autopsy should not be held to determine the nature of the fatal disease because, if this was unknown to the physicians, the death should have been reported for medico-legal investigation.
- The *medico-legal* or *forensic autopsy*, which is performed on the instructions of the legal authority responsible for the investigation of sudden, suspicious, obscure, unnatural, litigious or criminal deaths. This legal authority may be a coroner, a medical examiner, a procurator fiscal, a magistrate, a judge, or the police, the systems varying considerably from country to country.

  In most systems the permission of the relatives is not required, as the object of the legal investigation would be frustrated if the objections of possibly guilty persons could prevent the autopsy.

  In many jurisdictions the medico-legal autopsy is often further subdivided into:
- those held on apparently non-criminal deaths, such as accidents, suicides, deaths from sudden natural causes, or associated with medical and surgical treatment, industrial deaths, and so on
- the truly forensic autopsy held on suspicious or frankly criminal deaths, usually at the instigation of the police. These deaths comprise murder, manslaughter, infanticide and other categories that vary in different jurisdictions.

Autopsy legislation, guidelines, standards

Discussions about the correct performance and quality of the autopsy started at the beginning of the nineteenth century. When Virchow started in 1844 as assistant to the Prosector at the Charité in Berlin, he found a rather disorganized autopsy facility where most of the autopsies were performed by the youngest, not yet fully qualified, physicians without any basic training in autopsy technique. This was the starting point for the publication of his book on autopsy technique.[8]

Probably the best-known regulations from that era concerning medico-legal autopsy are the Austrian decree of 1855 and the Prussian edict of 1875. The former included, in its 134 paragraphs, very detailed instructions as to the performance of medico-legal autopsies. It is noteworthy that it is still valid legislation in Austria.[1,9,10] It took about another 100 years until various national organizations in the industrialized world, mainly professional bodies, began to take an interest in autopsy guidelines.[11–14]

In addition to the national measures to create guidelines and to harmonize the medico-legal autopsy, there has been international interest in achieving harmonized and internationally recognized rules on the way autopsies should be carried out. In 1991, the General Assembly of the United Nations endorsed the Model Autopsy Protocol of the United Nations. The European Council of Legal Medicine (ECLM) document *Harmonisation of the Performance of the Medico-Legal Autopsy* was adopted by the General Assembly in London 1995. The latter document served largely as basis for the pan-European Council of Europe – *Recommendation No. R (99) 3 On the Harmonisation of Medico-Legal Autopsy Rules and Its Explanatory Memorandum* – which was adopted by the Committee of Ministers in February 1999 (see Appendix 1).[15] Although the document is a 'recommendation' by nature, it has legal implications, because Council of Europe member countries have to implement these principles into their national legislation.

The idea of quality control and quality assurance, first introduced into industrial production of goods in the twentieth century, found its way into medicine later via laboratory medicine. Although regional and national differences in this respect are huge and the pace of progress has generally been very slow, the need for standards in specialist education, continuing professional development, harmonization of investigative procedures and necessity of quality systems is now better understood. As guidelines usually

Box 1.1 Accreditation

Accreditation is a procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks. This aims to increase the credibility and acceptability of the reports and certificates issued by them. It is achieved by ensuring that the infrastructure, personnel and the methods comply with pre-established criteria. The structure, processes, policies and goals of the body to be accredited are described in a quality manual. Standard operating procedures (SOPs) have to be defined to describe the specific tasks that will be carried out at the entity.

International Organization for Standardization (ISO) and ISO's sister organization, the International Electrotechnical Commission (IEC), are the world's largest developers and publishers of International Standards and a network of the national standards institutes of 163 (10.1.2011) countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that co-ordinates the system.

The International Laboratory Accreditation Cooperation (ILAC), is an international co-operation of laboratory and inspection accreditation bodies. European co-operation for Accreditation (EA), is the European network of nationally recognized accreditation bodies located in the European geographical area. According to the Regulation (EC) No765/2008 of the European Parliament and of the Council of 9 July 2008, the main mission of the EA is to promote a transparent and quality-led system for the evaluation of the competence of conformity assessment bodies throughout Europe and to manage a peer evaluation system among national accreditation bodies from the European Union member states and other European countries.

Accreditation procedures have usually been applied to calibration and testing laboratories but the European Network of Forensic Science Institutes (ENFSI) and EA are currently working in a joint project aiming to define which standard, ISO/IEC 17020 or ISO/IEC 17025, is to be used for the different forensic fields. Several German and Swiss institutes of legal medicine have recently been accredited by their respective national accrediting bodies regarding medico-legal activities including autopsies.

represent recommendations allowing some variation in practice, the most recent trend, particularly in medico-legal field, seems to be moving towards accreditation that necessitates standardized operational procedures.

The type of pathologist that deals with these categories also varies from place to place but, as the systems are so diverse, there is little point in discussing the details. What is much more important is that whichever pathologist tackles each type of case, he or she should be trained and experienced in that particular field. Unfortunately, either from lack of staff and resources or because the system is deficient, medico-legal autopsies – especially of major criminal cases – are frequently performed by pathologists inexperienced in forensic procedures. According to Spitz most medico-legal autopsies in the USA in the 1980s were performed by hospital pathologists with little or no medico-legal training or experience.[16] Even today more than half of the USA states still have county coroners, an office for which no medical training is necessary, and there were in 2009 only about 500 trained forensic pathologists in the nation's more than 3000 counties.[17]

Another serious defect in many countries is the separation of those who practise forensic pathology from those who profess to teach it in universities. It is impossible to be a credible and convincing teacher unless one has continuing practical experience of the subject.

When quality assurance measures do not exist or fail, systemic errors may remain undetected for longer periods of time. When eventually detected the repercussions can be serious; they can be costly to society, not only in terms of money but also in loss of confidence as to the rule of law, and involve personal tragedies for those affected.

A good example of the repercussions of such practices was revealed in the recent Inquiry into Pediatric Forensic Pathology in Ontario. It was established by the Government of Ontario under the Public Inquiries Act on April 25, 2007 to address serious concerns over the way criminally suspicious deaths involving children were handled by the Province of Ontario in Canada from 1981 to 2001. The Inquiry's mandate was to conduct a systemic review and an assessment of the policies, procedures, practices, accountability and oversight mechanisms, quality control measures and institutional arrangements of paediatric forensic pathology in Ontario.[18]

Even more unfortunate is the performance of medico-legal autopsies by doctors who have no training in pathology at all. Though lack of resources makes this a widespread and inevitable practice in many developing countries, the same regrettable practice is seen in some parts of Europe, the Americas and elsewhere. This is to the detriment of the high standard of expertise that is vital for the support of law enforcement and the administration of justice. A poor opinion is often worse than no opinion at all, as in the latter case, the legal authorities will at least be aware of the deficiency in their evidence, rather than be misled by the often dogmatic inaccuracies of an inexperienced doctor.

The procedure for a forensic autopsy

Though the actual performance of an autopsy is fairly uniform whatever the nature of the death, there are a number of associated matters that vary according to the circumstances. For example, the procedural precautions required in a murder are not necessary in a sudden natural death, and the dissection in a criminal abortion or fatal rape is different from that upon a drowned body.

There are, however, many facets of the autopsy that are common to every death. These will be discussed in turn here, though the full significance of each item is discussed in detail in other chapters.

Box 1.2 The objectives of an autopsy

- To make a positive identification of the body and to assess the size, physique and nourishment.
- To determine the cause of death or, in the newborn, whether live birth occurred.
- To determine the mode of dying and time of death, where necessary and possible.
- To demonstrate all external and internal abnormalities, malformations and diseases.
- To detect, describe and measure any external and internal injuries.
- To obtain samples for chemical, toxicological or genetical analysis, microbiological and histological examination, and any other necessary investigations.
- To retain relevant organs and tissues as evidence.
- To obtain photographs and video for evidential and teaching use.
- To provide a full written report of the autopsy findings.
- To offer an expert interpretation of those findings.
- To restore the body to the best possible cosmetic condition before release to the relatives.

Preliminaries to an autopsy

Before the body is even approached, a number of preliminaries are necessary.

Authorization and consent

A medico-legal autopsy is carried out at the behest of the appropriate authority. The pathologist must not begin his examination until he is satisfied that such authority has been issued in respect of that particular death. The means of delivering such authority will vary from place to place: it may be a written document, a verbal or telephoned message, or a tacit standing arrangement.

Where two official organizations are involved, it must be clear who has the premier right to order an autopsy. For example, in England and Wales, the police may request a pathologist to examine a body externally at the scene of death, but the right to order an autopsy is the sole prerogative of the coroner. Though in serious incidents he or she should take the advice of the Chief of Police regarding the choice of a pathologist, the final decision remains that of the coroner.

As stated earlier, in a medico-legal autopsy the relatives are not consulted for their consent to autopsy, as such permission cannot be withheld. As a matter of courtesy it is usual to inform them before the autopsy is carried out unless the circumstances are too urgent. In most cases, however, a relative will have attended to identify the body before the examination begins. Pathologists should be cautious about performing autopsies where the authorization or consent aspects are not clear. It sometimes happens that a 'consent document' for a hospital death has been obtained but the case has later been reported for medico-legal investigation. The pathologist should not then proceed under the 'consent' authority until the coroner or other official has decided whether to order his own autopsy (perhaps using another pathologist). If that official decides not to proceed, then usually the consent document becomes valid once more.

Permission for the retention of material from an autopsy (ranging from small fluid samples to the entire body, if necessary) is usually covered in a medico-legal case by the original authority issued for the examination. There is, however, considerable variation in the legal aspects of tissue and organ retention in different countries, and each pathologist must become fully conversant with local regulations.

In the legislation controlling the English coroner, it is not only permissible, but also obligatory, for the pathologist to retain any tissue that may assist in the further investigation of the death.

However, the coroner (or procurator fiscal in Scotland) has only a negative power to forbid the use of tissues or organs for purposes other than the investigation of the death, and so cannot give positive consent for the use of these for transplantation, teaching or research; such permission must be obtained from the relatives, if the coroner does not object, under the Human Tissue Act 2004.[19–21]

Who may be present at an autopsy

Once again, each nation or state has different legislation and regulations on the conduct of medico-legal examinations. Though it is pointless to try to survey these, it must be emphasized that every pathologist must learn and abide by the laws applicable to his or her position.

Often the relatives of the deceased person, or an accused person, must be informed of the place and time of the autopsy so that they may be represented by a lawyer or doctor acting on their behalf. In some jurisdictions, including Britain, there is nothing that specifically forbids the relatives attending in person and the authors have had several experiences of this nature. It is open to the pathologist to refuse to conduct the autopsy if he objects to their presence.

In many homicides, a second autopsy is performed by another pathologist acting on behalf of the defence lawyers representing the accused person. This usually takes place at a later date, after the accused has been charged and granted legal representation, but sometimes the second pathologist will attend the original autopsy. This is quite in order and is more valuable than a later exploration of extensively dissected and autolysed tissues.

The permission for such attendance is granted by the coroner, medical examiner or equivalent legal authority. The first pathologist should grant his colleague every courtesy and facility in the expectation of similar behaviour when the roles are reversed.

Others entitled to be present naturally include the officials or deputies of the department ordering the autopsy – for example, a coroner, magistrate or judge. The police, including their technical teams, are also present if the death is criminal or suspicious. Whether other doctors and medical students are allowed depends upon the wishes of the official commissioning the examination. When the deceased has been under medical care before death, it is almost invariable practice to allow – and indeed encourage – the physician to be present, as he has the best knowledge of the medical history.

In a criminal or suspicious case, the pathologist should try to limit the number of those present to a minimum. Not only is there a greater risk of loss of confidentiality, but sheer physical numbers, can make the mortuary overcrowded. This hampers movement, causes distraction, and adds to the risk of infection and contamination, especially with the present concern about the various forms of hepatitis (B, C, D, E), tuberculosis and human immunodeficiency virus (HIV) infectivity. No one should be present merely as a casual observer, not even senior police officers not directly involved in the investigation. With the increased sophistication and complexity of forensic and police procedures, more and more people cram into the mortuary, cluttered with cameras, videos, recorders, scene-of-crime kits and so on, until there is hardly room for the pathologist to move.

Whoever is present at an autopsy on a criminal or suspicious death should be listed and named by the pathologist on the autopsy report.

Examination of the scene of death

In homicide, suspected homicide and other suspicious or obscure cases, the pathologist should visit the scene of the death before the body is removed (Figs 1.1–1.3).

Once again, local practice varies but any doctor claiming to be a forensic pathologist should always make himself available to accompany the police to the locus of the death. This duty is often formalized and made part of a contract of service for those pathologists who are either full-time or substantially involved in assisting the police. In England and Wales, the ‘Home Office Pathologists’ are permanently on call for such visits and in many other jurisdictions, such as the medical examiner systems in the USA and the European State and University Institutes of Forensic Medicine, there is usually a pre-arranged duty roster for attendance at scenes of death. The function of an experienced forensic pathologist at the scene of death is generally to assess the environment, the local circumstances, and the position and the condition of the body. In a large proportion of instances crime can rapidly be excluded in favour of accident, suicide or even natural causes. This is a most useful and cost-effective function, as a spurious murder investigation involving perhaps scores of police, many vehicles and other expensive public facilities, may be disbanded promptly when the pathologist recognizes innocent circumstances.

The pathologist should always have appropriate equipment ready to take to a scene investigation at a moment's notice. Further equipment may be carried if autopsies have to be carried out in places where good mortuary facilities are not available. Most forensic pathologists carry a 'murder bag' in their car and though every expert has his own choice of equipment, the following is a reasonable inventory:

Box 1.3 Equipment for scene of crime investigation

- Waterproof apron, rubber gloves and disposable overalls and mask.
- Thermometer, syringes and needles, sterile swabs.
- Autopsy dissection set, including handsaw.
- Cutting needles and twine for body closure.
- Swabs and containers for blood and body fluids.
- Formalin jars for histological samples.
- Plastic bags, envelopes, paper, spare pen and pencil.
- Printed body charts for recording external injuries.
- Hand lens, electric torch, digital dictaphone or mini-tape recorder.
- Digital or 35 mm single-lens reflex camera with electronic flash or digital video camera.

The thermometer can be either a long chemical mercury type, reading from 0 to 50°C, or the more modern electronic digital variety with a probe carrying a thermocouple. The amount of equipment varies with the facilities likely to be available. In developed countries there are likely to be good mortuary facilities available in a hospital or municipal mortuary and the police forces will have extensive scenes-of-crime expertise with photography, specimen containers and so on. In developing countries and the more remote areas of other states, the pathologist may have to be virtually self-sufficient in respect of both crime investigation and the subsequent autopsy.

In addition to medical kit, the experienced forensic pathologist will always have appropriate clothing such as rubber boots and rain- or snow-wear ready to hand for any call.

When at the scene of death, the pathologist's actions are dictated by the particular circumstances. Much will depend upon the availability or otherwise of police and forensic science assistance. In Britain, for example, several teams converge on a scene of crime, including photographers and video-operators, and scenes of crime officers (SOCOs), formerly known as crime scene investigators (CSIs), whose function is to preserve and protect the crime scene so that evidence is not spoilt or destroyed, collect trace evidence such as fibres, blood, hair, paint or glass, search and collect fingerprints, footprints and toolmarks. Scientists from the nearest forensic laboratory often attend with their police liaison officers, as well as fingerprint officers and, of course, the investigating officers from the Criminal Investigation Department.

Where no such backup is available, the pathologist must try to collect trace evidence himself, but he should remain within the limits of his own expertise.

The pathologist should accept the instructions of police officers in relation to the approach to the body so as to preserve the immediate environment as much as possible. Out-of-doors access is often limited to a single pathway marked by tapes, and in a building, a track to the corpse is usually pointed out by the detective in charge.

The doctor should not touch anything unnecessarily and certainly not smoke or leave any object or debris of his or her own. Increasingly, those visiting the scene of a crime are given disposable overalls and overshoes to wear, so that fibres, hairs and so on from the visitor are not spuriously transferred to the scene.

If a forensic doctor has to act both as pathologist and clinical medico-legist or 'police surgeon' (that is, examining live victims or suspects), he or she must change clothing or wear a new set of protective garments to avoid transferring trace evidence, such as fibres or hairs, from victim to suspect.

The pathologist should observe a great deal, but do very little. He or she should note the position of the body in relation to nearby objects and establish the plan of the premises if indoors. A sketch or his own photograph is sometimes useful, and it is advisable to use a digital or video camera for instant recording of the death scene.

Any obvious cause of death should be observed, and any blood pools or splashes noted in relation to the position of the corpse. The shape of such splashes should be observed, as blood striking perpendicularly to a surface leaves a circular mark, whilst that landing obliquely is pear-shaped, with the sharper end towards the direction of flight (Fig. 1.4).

Figure 1.1 The scene of a rape-homicide. The attending pathologist must record the posture, state of clothing and general relationship of the victim to the surroundings, but limit the examination at the scene to avoid any interference with the vital process of obtaining trace evidence. Rectal temperatures should not be taken until all swabs are completed, usually in the mortuary. Temperatures can be taken in the ear or deep nostrils, though with severe head injuries (as here) even this must be done with care.

Figure 1.2 Scene of a homicide-suicide where the locus of bodies should be widely marked off by tape to restrict access, and the actual body protected by a shelter from the weather and unauthorised onlookers.

Figure 1.3 Scene from inside of the cordoned area of Figure 1.2 with scene of crime officers and one of the victims.

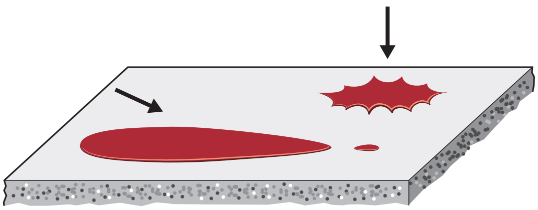

Figure 1.4 At a scene of crime, the position of the body at the time of an assault can sometimes be clarified by observing the direction of blood splashing that may have been thrown off a weapon or blood-stained hands. Blood striking vertically causes round or crenellated circles, while blood hitting at an angle is lance-shaped, with the narrow end facing the direction of travel. There is often a preceding drop of blood in advance of the major splash, forming an 'exclamation mark' stain.

When photographs have been taken of the body in its original position, the pathologist then approaches it, after checking with the investigating officers that it is appropriate for him to do so. Close examination can be made and the skin felt to assess temperature. The eyes, neck and hands can be examined and where necessary, clothing gently moved aside to look at the throat or upper chest. Any relevant findings should be photographed by the police before further disturbance.

If forensic scientists or SOCOs require any samples at this stage, their wishes must be respected. They may want to 'tape' the body, that is, press adhesive tape across the skin and clothing to capture any loose hairs and fibres. The body can then be moved to look at the sides and undersurface, again with caution so that no weapon, other object or trace evidence is disturbed. No set routine can be advised, as each case has its own individual aspects. The prime object is to assess the whole scene while causing the least disturbance to the body and clothing before the scientific teams have finished their tasks (Fig. 1.12).

Estimating the post-mortem interval at the scene

The last sentence above raises the matter of estimating the time since death. The problem is fully discussed in Chapter 2, but has relevance here in relation to the pathologist's actions at the scene of death.

The general warmth or coolness of the hands and face can be assessed by touch, and the degree of rigor mortis felt by gently testing the limbs. The ambient (environmental) temperature must be taken as soon as possible after the discovery of the body, preferably by police SOCOs who usually arrive at the locus before the pathologist. The ambient temperature should be taken as near to the body as possible, as microenvironments can exist, even inside buildings or rooms. Information should be sought as to how much disturbance of the ambient temperature might have occurred, such as opening doors and windows, or turning fires or central heating on or off, so that some idea of post-discovery distortions of temperature can be estimated later. The insertion of a thermometer into the rectum at this stage in the investigation, as advocated by some textbooks, is controversial.

At a scene of death, this usually means either pulling down trousers or pants, and otherwise disturbing clothing, often in cramped and ill-lit places, frequently out in the open. It also risks contaminating the rectum and perineum, by introducing seminal fluid from the anal margin into the rectum, making subsequent examination of that area (and taking swabs for semen) of reduced value. As so many violent crimes now have sexual or homosexual overtones, the practice of taking rectal temperatures at the scene should be performed only if the forensic scientists or police SOCOs are satisfied that trace evidence from the clothing, swabs from the vulva, vagina and anus, etc., can be obtained satisfactorily before rectal thermometry is performed.

In other words, a cost–benefit analysis must be made at the scene, to decide if the difficulties of taking a rectal temperature are worth the small potential advantage of an earlier measurement. In many cases, where the body has obviously been there long enough for the core temperature to have reached ambient – or where other circumstantial evidence has indicated that the time of death is known to a greater degree of accuracy that can be hoped for by thermometry – then nothing is lost by postponing the procedure until the body arrives at the mortuary for autopsy, which, in British practice, is usually directly after the body is moved from the scene.

If the autopsy is to be delayed for many hours owing to difficulties with transport or lack of facilities, then much more must be done at the scene and temperature measurements are justified.

An alternative is to use a place other than the rectum. The axilla and mouth give low readings, which cannot reliably be correlated with the deep temperature because of variable exposure to the air temperature. More useful is the auditory meatus or nostril, the thermometer or thermo-couple probe being inserted as deeply as possible. Reliable, reproducible readings can be obtained from these sites, which have the great advantage of being easily accessible without moving clothing, as well as not being required for swabbing to investigate possible sexual assaults. The use of temperatures to attempt to calculate the post-mortem interval is discussed fully in Chapter 2.

When the pathologist has made the best examination possible in the circumstances, his next function is to ensure that the corpse is removed to the mortuary for autopsy with the least disturbance and loss of evidence. He should supervise the removal himself or at least delegate the duty to another person whom he knows is careful and competent. Each hand should be enclosed in a bag, secured at the wrist by adhesive tape or string. A similar bag should be placed over the head. The packaging medium may vary, but generally paper bags are recommended.

The body should be placed gently in a 'body-bag', which has a zip closure, or moved on to a large, new plastic sheet, at least 2 metres square. If a sheet is used, the edges should be wrapped over the body and secured with adhesive tape. The object of the exercise is to retain any loose objects, hairs and fibres that may be adhering to the body or the clothing. The sheet or bag is taken by the forensic laboratory after the body is removed in the mortuary so that they may screen it for trace evidence. The transport of the body is the responsibility of the police or other agency such as the coroner or his officer. The body in its plastic wrapping should be placed in a rigid fibreglass 'shell' or ordinary coffin, and taken by hearse, van or police transport to the chosen mortuary.

Physical damage during the removal should be avoided as much as possible, though in difficult or inaccessible sites this is easier said than done. In fires, the body may be seriously damaged before or during recovery, sometimes because its presence is not suspected in the smoke-filled, often waterlogged, debris of a conflagration. The author (BK) has experience of such a scene where firemen walked over two bodies for several hours before it was realized that they were buried under burnt furniture and other debris. Handling brittle, charred, bodies can easily cause the splits at joints that may mimic ante-mortem injuries (see Chapter 12).

In summary, the function of a pathologist at any scene of suspicious death is to observe the situation, to conserve any fragile evidence, to supervise the removal of the body and offer an opinion, based on experience, about the nature of death where this can reasonably be done. He is not there to act as a latter-day Sherlock Holmes, voicing unsubstantiated theories on non-medical matters, nor attempting to overinterpret the situation from the flimsiest of facts. The pathologist is part of a team of specialists, all experts in their own field, and it is as a member of such a co-operative, co-ordinated group that his best contributions can be made.

Property, clothing and identification

Whether or not the pathologist has been to the scene of a death, he should take notice of the clothing and other property of the body upon which he is to carry out an autopsy. This applies not only to every criminal or suspicious death, but also to many traffic and industrial accidents, as well as to the victims of falls from a height, drowning and so on.

In many instances, there will be no opportunity to examine the clothed body in the mortuary: if death has occurred in hospital or in an accident department, the clothing may have been removed before transfer to the mortuary. The pathologist should make a permanent request that a body from any traffic accident, or other case where trauma was the provisional cause of death, should be brought to the mortuary without having the clothing removed by police or nursing staff – unless of course the victim was still alive on arrival at hospital, and undressing was performed before attempted resuscitation or treatment. As a second best, the removed clothing should accompany the body to the mortuary so that it can be examined, if necessary, for damage, stains and other evidence. Unfortunately, such clothing is frequently destroyed before it can be seen.

The mortuary staff should be trained to regard clothing and property as important items of evidence, and a system should be established to retain, identify and store these, both from the evidential aspects and for the safety of valuables. The contents of the pockets, documents, keys and other items all assist in identification. Though primarily the task of the police, the pathologist will sometimes have an interest in this aspect. The clothes themselves, the style, fabric, colour and labels all assist in identity.

In trauma deaths, the injuries on the body should be matched up with damage on the clothing. Tears, slashes, stab wounds and especially firearm wounds in the clothes must be compared with the position of external lesions on the body, making allowance for movement and displacement during life. Some self-inflicted wounds may be confirmed by the non-alignment of the clothing damage with the injuries (see Chapter 8).

Blood, seminal, vaginal and other body secretions may be found on the clothing, and though this is primarily the responsibility of the forensic science laboratory, the pathologist may be the first or only person to detect their presence. In firearm deaths, gunshot residues on the clothing may be vital evidence about the range of the discharge and the identity of the ammunition.

In traffic fatalities, tearing of the clothes, grease marks, road dirt, broken lamp or windscreen glass, and even metallic or paint fragments from the vehicle may all assist in reconstructing the event and in identifying the unknown vehicle in a 'hit-and-run' tragedy.

Other objects associated with the body that may be helpful include medicines, which may assist in determining the nature of the disease from which the deceased had suffered, for example, glyceryl trinitrate (GTN) or insulin. In some suicides, empty drug or poison containers may be with the body. Other helpful artefacts include such items as hearing aids, syringes, external pacemakers and inhalers. The clothing must be removed carefully and, especially in criminal or suspicious cases, the pathologist should supervise and assist the mortuary technician, especially as some technicians are not always aware of the importance of clothing in the reconstruction of events.

If the body is not bleeding or otherwise fouled, it is best to remove clothing in the usual way by pulling over the head and limbs, unless this might interfere with any injuries or soiling. If rigor is intense or if there is blood on the face or hands, it may be advisable to cut off some or all of the clothing. This should be done after consultation with the forensic scientists, if they are present, so that the cuts will be made where they will least interfere with later laboratory examination. In any event, cuts should avoid passing through pre-existing damage or staining of the garments. Each item of the clothing should be placed separately into a paper bag to allow them to 'breathe'.

Identification of the body

The identification of an unknown body is a major forensic exercise, and is fully discussed in Chapter 3. Here, however, we are concerned with the formal recognition of the subject of an imminent autopsy. Before a pathologist makes any examination (and certainly before he begins any mutilating dissection), it is essential that he ensures that the corpse before him is indeed the correct person.

In every medico-legal case, some responsible person must have identified the body. This is usually a relative or close friend of the deceased person, who looks at the face of the body and verbally certifies to a police officer, mortuary attendant or doctor that it is indeed 'John Smith'. Where the body is burned beyond recognition, mutilated or putrefied, attempts at identification must be made by showing the relative documents, or items such as clothing or jewellery.

In non-criminal cases, such as sudden deaths and most accidents and suicides, the continuity of identity is carried on by a label or tag attached to the body by the police officer, nursing staff or mortuary attendant, which carries the name, address, serial number and other relevant details. This label may be tied firmly to a toe, or a durable wrist or ankle bracelet may be used. Some mortuaries write the name on the leg with an indelible marker, but this can be smudged or obscured during autopsy.

The pathologist should always satisfy himself of the identity by comparing the documents authorizing the autopsy with the toe label or bracelet. The details should agree and, if they do not, he should not proceed with the autopsy until the discrepancy is cleared up, if necessary by calling back the police officer or even the relative to make absolutely sure of the identity.

Many mistakes have been made in the past, with adverse publicity, embarrassing enquiries and even legal consequences. Autopsies on the wrong person, incorrect causes of death, relatives attending the wrong funeral and even cremation of the wrong body are regularly reported as a result of laxity in identification. To avoid confusion, the body should always be labelled as soon as it arrives in the mortuary. Labels on shrouds become detached and those on refrigerator doors are unreliable, as other parties (such as night porters) may shift occupants around without the knowledge of the pathologist or regular mortuary staff.

Some large mortuaries use special means of identity. One known to the authors has an automatic camera fitted in the ceiling of the mortuary entrance. Every new body wheeled in is photographed on its trolley with a serial number prominently displayed on a board placed across the upper chest, so that the face appears with the record number to resolve any later discrepancy.

In serious cases such as homicide, the pathologist must not rely on second-hand evidence of identity such as a toe label. Before the autopsy, someone must verbally confirm to him that the body they are both then viewing is 'John Smith'. This person must be either a relative or the police officer to whom a relative has already formally identified the corpse.

The pathologist must record in his autopsy report the date, time and particulars of the person identifying the body to him, so that 'continuity of evidence' is ensured for legal purposes, which cannot successfully be challenged by the defence at a subsequent trial.

The use of the history of the case

As in clinical medicine, the history of the deceased 'patient' or victim is a vital and indispensable part of the investigation. The extent to which it should influence the pathologist in coming to a decision as to the cause of death, however, is more controversial, as is discussed below.

In medico-legal autopsies – compared with hospital 'clinical' cases – the history is often scanty, absent or misleading. If a person has been found dead, having had no previous medical attendant, there may be virtually no information at all. In criminal deaths, the person who knows most about the death may well be the perpetrator, who naturally may remain silent or give a distorted, misleading or totally false account of the circumstances. The forensic pathologist then often has to contend with a scanty or incorrect history.

Even when a story is given in good faith by relatives, the medical facts are often distorted because of incomplete knowledge and understanding. It may be further warped by transmission by a police officer or other non-medical person, so that only a garbled history reaches the pathologist. The latter should attempt to supplement deficiencies in information by further requests to the commissioning authority, such as the coroner or the police. Wherever possible, the pathologist should try to contact the doctor who may have treated the deceased in the recent past. In the urgency of forensic work, however, frequently at night or weekends, the autopsy may have to proceed without any additional history.

Though more detail may be obtained afterwards, the course of the autopsy might well have been different if such knowledge was available beforehand. For example, the author (BK) once performed an autopsy on a coal miner with no history other than a knowledge of his occupation and chronic chest disease. Autopsy revealed sufficient cardiopulmonary disease to account for death and the body was released for burial. It was not until the following day that the police in the rural area where the male had died, tardily produced the information that both an empty bottle of sleeping tablets and a suicide note had been found with the body. Paradoxically, the history is often less important in violent deaths where the wounds are self-evident, though a good description of the circumstances may assist in interpreting the direction of injuries, the nature of the weapon and other aspects.

In most autopsies the history directs the pathologist to the appropriate ancillary investigations, as should have happened in the case described above. Some pathologists have in the past advocated that the autopsy should be performed ‘blind’, so that the history does not prejudice the opinion of the pathologist. This is patently impracticable, for every autopsy would then have to be totally comprehensive, including such techniques as the removal of the spinal cord in every case, and all possible ancillary investigations, such as toxicology, microbiology, virology, radiology, diatoms, histology and so on, as there would be no means of knowing what was necessary and what was irrelevant. Apart from the intolerable burden of work, the expense of such an approach would be prohibitive, if applied to all autopsies.

A particular difficulty often arises in relation to bodies returned to a home country after death in a foreign state. The problems vary greatly with the degree of both pathological and administrative sophistication of the foreign country. Where these are poor, then the problems of obtaining a good – or even any – history may be great, even after attempts at using international police or diplomatic channels.

Sometimes, a ‘doctor-to-doctor’ approach by telephone, email or fax may be the best way of obtaining information. Even a cause of death from the foreign country may be either unobtainable or so vague (such as ‘heart failure’) as to be useless. Previous autopsies may be incomplete, of poor quality or even fraudulent, such as finding a stitched skin incision but no underlying dissection of organs. Several surveys of such problem autopsies have been published, with a plea for some kind of international death certificate.[22,23]

Difficulties arise when objective autopsy findings are scanty or even absent. The pathologist then has the dilemma of choosing between a cause of death based on a subjective knowledge of the alleged history (which may be wrong) or admitting that the cause of death is unascertained.

This problem, fully discussed by Leadbeatter and Knight, Cordner and Pollanen, is by no means uncommon.[24–26] For example, sufferers from epilepsy or asthma are known to die suddenly and unexpectedly, an autopsy usually revealing no adequate morphological cause for their death. Another prime example is sudden infant death syndrome (SIDS), discussed in Chapter 21, where by definition there are no significant autopsy lesions and the history is usually essentially barren.

In hypothermia where the patient is warmed up in hospital but dies in a day or two, there may be nothing to find at autopsy, yet there is firm clinical history of a rectal temperature of 26°C. Moving to more forensic cases, a body may be recovered from a river after clothing and a suicide note have been found on the bank – yet at autopsy there may be no visible evidence of drowning whatsoever.

In these cases, should the pathologist – in the absence of objective evidence of hypothermia or drowning – decline to offer a cause of death and perhaps be accused of being obstructive or perverse? Or should he certify ‘hypothermia’ or ‘drowning’, and perhaps be challenged in court by a lawyer who claims that the pathologist relied only on hearsay and has no objective evidence to offer?

The best course is for the pathologist, if he feels that the history is sufficiently strong, to give the most likely and reasonable cause of death, but make it clear in his discussion in the autopsy report that this opinion is based on a consideration of the circumstances and is not a dogmatic statement of the kind that could be offered if the victim was shot through the brain. Where a summary of the history prefaces the autopsy report, the pathologist should be careful to indicate what is ‘hearsay’ as far as he is concerned. Thus he should not say ‘The deceased was struck on the head by two males’, but ‘I was told that the deceased was struck on the head by two males’.

As is discussed later, the autopsy report should not be merely a bald recital of the anatomical findings, but should have a final commentary that includes a ‘differential diagnosis’ where the cause of death is not clear cut, as well as a justification for the eventual opinion or an admission that there is no way of deciding between alternative possibilities.

The main difficulty arises with the actual ‘cause of death’ phraseology, which will be entered into the legal and national records in the format required by the World Health Organization (WHO). This gives no opportunity to express preferences or give explanations but, on the ‘best-guess’ principle, the pathologist can do no more than enter his most reasoned choice or, with legitimate honesty, state that the cause is ‘undetermined’.

Precautions regarding potential infective conditions and other risks and hazards in autopsy room

The autopsy room as a working environment poses a number of health and safety risks and hazards to individuals working there. These can be minimized by awareness, appropriate design of the facility, adoption of safe working practices, proper supervision and management. The main risks include: infection; physical risks due to injuries associated with the use of sharp instruments or due to sharp bone fragments or other dangerous foreign objects such as exploding bullets hidden in the body or when performing necropsy on a body contaminated by toxic chemicals or radioactive materials; injuries resulting from lifting heavy loads or slipping or falling due to slippery floor; or electrocution due to faulty equipment, incorrect fittings or poor maintenance.

Risk of infection

Every cadaver has to be considered carrying a potential risk for infection as very often the death has been unwitnessed, there is no knowledge of the circumstances of death nor any previous history of the deceased and even the identity of the person may be obscure. As many forensic situations involve drug abusers and persons with promiscuous sexual behaviour, the statistical risk of HIV and concomitant tuberculosis or hepatitis infection is probably greater than in the general autopsy population. This poses a risk to pathologists, mortuary staff, police and laboratory staff who may deal with post-autopsy samples.

Pathogens can be aquired through skin injuries due to sharp bone fragments, scalpel or needle stick injuries or inoculation through pre-existing skin injuries, through the mucous membranes of the eyes, nose or mouth or possibly even by inhalation of blood-containing aerosols. A great deal has been written about such risks but no consensus has yet been reached; a recent review has been published by Burton.[27] The first case of documented seroconversion after occupational exposure to HIV was reported in 1984.[28] Since then altogether 106 documented occupationally-acquired HIV seroconversions and further 238 possible occupationally-acquired infections have been reported worldwide (data to December 2002) in a summary of published reports by the Health Protection Agency in the UK published in 2005. The true incidence of occupationally-acquired HIV infection is unknown but probably higher. The reported cases include altogether four subjects belonging to an occupational group defined as embalmer/mortuary technician. In one of them the mechanism of exposure was deep percutaneous injury sustained by a bone saw during autopsy.[29] In the three other subjects occupationally-acquired infection was considered possible.[30] Johnson and coworkers have published a well-documented case of autopsy-acquired HIV infection in a pathologist who sustained a 1 cm deep scalpel wound to the hand while reflecting the scalp.[31]

One school maintains that all autopsies should be carried out with total precautions against infective risks, so that it does not matter what case is handled. However, this is almost impossible to achieve in a busy coroner or medical examiner practice and does not solve the problem of possibly infected material being sent out to other laboratories.

Another regime is to carry out pre-autopsy testing for HIV and hepatitis, using blood from a femoral needle puncture. The result can often be returned within hours, when a decision may be made as how to handle the autopsy – or even whether to abandon it, if the risk–benefit aspect is high. More usually, a positive result will result in the autopsy being carried out with special care, additional protective clothing, visors, masks and metal gloves, with restriction of access to observers, choice of more senior technicians and warnings sent to laboratories liable to handle samples.

The time for which a corpse remains potentially contagious with HIV is variable. Infectious virus has been recovered from liquid blood held at room temperature for 2 months and virus in high concentrations has been found to remain viable for 3 weeks.[32] Fiftyone (51) per cent of the virus has been shown to survive in plasma and monocyte fractions from infected cadavers up to 21 hours post-mortem.[33] Other series found survival in corpses from 18 hours to 11 days after death. Virus has been recovered from the spleen after 14 days post-mortem. Refrigeration seems to make little difference to viability. Douceron and co-workers cultured blood and effusions from refrigerated bodies and obtained viable virus up to 16 days post-mortem and concluded that there was no safe maximum time at which corpses ceased to be an infective risk.[34] In industrialized countries, it has become standard to offer post-exposure prophylaxis after significant percutaneous exposure to blood or tissues of HIV patients.

Other infections, such as tuberculosis, hepatitis viruses, anthrax, plague, Creutzfeldt–Jakob, Marburg, green monkey diseases, etc., are usually the subject of specific health and safety regulations, which vary from country to country.

Other toxic chemical or biological agents

Box 1.4 History

The use of toxic chemical or biological agents as weapon for murder or warfare goes back to antiquity. Toxic roots (hellebore – the siege of Kirrha, ~ 595 BC) and cadavers (Battle of Tortona, 1155) have been used to contaminate water supplies, plague-infected corpses have been catapulted into the besieged city of Caffa (now Feodosija, Ukraine) in 1346–1347 or deposited in the Swedish-held town Reval (now Tallin, Estonia) by Russians in 1710, to give just a couple of examples.[35,36] Despite the international treaties on the laws of war (Hague Convention of 1899 and 1907), prohibiting '*the use of projectiles the object of which is the diffusion of asphyxiating or deleterious gases*', numerous irritant chemicals and lung- or skin-damaging agents were tested and used during World War I. According to Wheelis, the Germans had even an ambitious programme of biological warfare directed against animals in neutral trading partners of the Allied forces from 1915 to 1918.[37,38] Before, during and after World War II the use of various toxic chemicals or biological agents has continued in individual invasions, interventions, wars and acts of terrorism.

The autopsy: external examination

In contrast to the 'clinical autopsy' performed to evaluate natural disease, the importance of the external examination is far greater in the forensic case, especially in deaths from trauma. In the latter, the medico-legal value of the external description may be paramount, as it is often from the outer evidence that inferences may be made about the nature of the weapon, the direction of attack and other vital aspects. Thus the forensic pathologist must spend all the time that is necessary in a careful evaluation of the body surface and not be too impatient to wield the knife (Fig. 1.5).

The routine for external examination will naturally vary according to the nature of the case but certain general principles apply. The following procedure is a useful baseline and may be adjusted according to personal preference. Variations in criminal cases to accommodate the needs of the investigating and scientific teams are mentioned later.

Figure 1.5 External examination must note every feature; here there is obvious abdominal distension in a battered child with facial bruising. The intestine had been ruptured by a blow and oxygen administered by the ambulance crew escaped to distend the peritoneal cavity.

- After identification and removal of any clothing, the race and gender are noted. The apparent age is assessed in children by size and in adults by changes in skin and eyes, such as the loss of skin elasticity, senile hyperkeratosis, Campbell de Morgan spots (haemangioma/cherry angioma),[39] senile purpura and arcus senilis. Hair colour, tooth loss and arthritic changes are also obvious signs of ageing. The apparent age should be compared with the alleged age and enquiries made about any obvious discrepancy, in case it is the wrong body, an error that plagues most autopsy rooms from time to time.
- The body length is measured from heel to crown (in infants, more detailed measurements are described later). Ensure that the attendant does not take the 'undertaker's height' from toe to crown, as due to the plantar flexion of rigor, this can be a considerable number of centimetres more than the live standing height.

  It should also be appreciated that the post-mortem height may differ from the known living height by several centimetres. There are several opposing causes of variation, which do not necessarily cancel each other. For example, muscle flaccidity allows joints to relax, unless rigor is present, but intervertebral discs appear to shrink, allowing shortening.
- The body weight in kilograms is measured if facilities are available; if not, it should be estimated. The weight of infants must always be measured. The general nutrition and physique is assessed in terms of obesity, leanness, dehydration, oedema, emaciation, and so on.

- The state of cleanliness, personal hygiene, hair and beard length, toenail and fingernail state, and urinary and faecal soiling and other associated signs such as emaciation, suggesting neglect by the person himself or a care giver, such as infestation by maggots (see Figs 2.13–2.15), is noted. Any parasitic infestation, such as fleas or lice, is combated before proceeding.
- The general skin colour is noted, especially hypostasis (discussed at length in Chapter 2). Congestion or cyanosis of the face, hands and feet is sought. Localized discolouration, especially unilateral in a limb (Fig. 1.6), suggests arterial embolism or incipient gangrene. Pink or brownish pink patches over the large joints may indicate hypothermia (Chapter 17). Other abnormal colours include the brownish hue of methaemoglobinaemia in some poisonings, the bronze speckling of clostridial septicaemia and the dark red of cyanide that somewhat resembles the cherry-pink colouration of carboxyhaemoglobin. Naturally racial pigmentation will modify the ease with which abnormal skin colouration can be seen.
- Congenital deformities of any type are recorded, from club foot (*talipes equinovarus*) to *spina bifida*, from a naevus to extra toes.
- Acquired external marks may be important for identification purposes or in relation to past injuries and disease. Tattoos (see Figs 3.1–3.4), body piercing, circumcision, amputations, surgical scars, old fracture deformities and scars of injuries, burns or suicidal attempts on the wrist and throat are noted. These are discussed further in Chapter 3. Increasingly, artefacts – both external and internal – arise from resuscitation attempts (Fig. 1.7) and must be carefully distinguished from original trauma. This emphasizes the importance of the history, to determine whether cardiopulmonary resuscitation was attempted by trained or untrained persons.
- The hands should be carefully examined for such signs as old and new injuries, defence wounds, bruised knuckles and electrical marks. The latter are often insignificant and difficult to see unless the rigor of flexed fingers is overcome, either by force or even cutting the flexor tendons at the wrist.
- Vomit, froth or blood may be present at the mouth and nostrils, and faeces and urine may have been voided. This must be correlated with the degree of post-mortem decomposition, which often leads to purging of fluids from orifices; most forensic pathologists have had the experience of being called by the police to the scene of 'a fatal haemorrhage', to discover only bloody fluid being purged by gases from a decomposing corpse.

  Vaginal discharge or bleeding is noted and the ears examined for leakage of blood or cerebrospinal fluid (CSF). Post-mortem ejaculation of semen from the external meatus is of no significance and can be seen in many different types of death. It is not particularly associated with asphyxial deaths, as sometimes stated.[40]
- The degree of rigor mortis is assessed by flexing the arms and legs to test the resistance. One should

Figure 1.6 Occasionally even minute changes in external examination, if correctly interpreted, can give a clue to the underlying cause of death. In this case a septic embolus due to bacterial endocarditis has led to a small skin necrosis on the big toe.

Figure 1.7 Post-mortem artefacts on the body of a sudden cardiac death victim. These are due to a mechanical chest compression device LUCAS (Lund University Cardiac Arrest System) applied by the paramedics after the male had collapsed on the street.

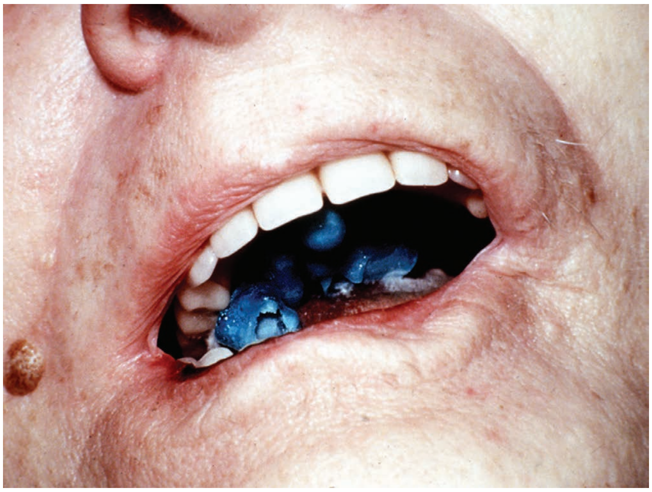

Figure 1.8 Full external examination is vital, including the interior of the mouth. Here a large number of amylobarbitone capsules offer a presumptive cause of death, though analytical confirmation is still required.

test both arms and legs, as sometimes a joint may be stiff as a result of a disease process or an old injury. If just a single joint is tested, it may give a wrong impression of the rigor. The significance of this and hypostasis is discussed in Chapter 2.

- Recent injuries (other than scars already noted) are carefully examined. In fact this part of the autopsy is often the most significant element of forensic cases. Injuries may be conveniently recorded in the mortuary by marking them on printed body diagrams. The forms can be secured on a clipboard and the data later transcribed into a written description for the autopsy report. The original diagrams should be retained, as their production may be demanded in court if there is controversy about any particular injury (Fig. 1.9).

All traumatic lesions should be clearly differentiated into abrasions, bruises, lacerations, incised wounds, burns and so on, according to the definitions given in Chapter 4. The shape and condition of the margins of each injury should be described where appropriate. It must be meticulously measured in terms of length, breadth, orientation to the axis of the body and the position with reference to surface anatomical landmarks. For example, a knife wound of the thorax might be described as follows, using ordinary language to explain any medical terms:

A stab wound was present on the left upper chest, placed obliquely, with the inner end lower than the upper outer end. The wound was 20 mm in length, which extended to 22 mm when the edges were opposed. The maximum width at the centre was 4 mm. The centre of the wound was just below the line joining the nipples, being 6 cm from the midline, 7 cm from the left nipple and 18 cm below the centre of the left clavicle (collar bone). The wound was 132 cm above heel level and was elliptical in shape, with the inner lower end slightly more sharply cut than the rather blunt upper end. The wound was shelved in a downwards direction, with subcutaneous tissue visible along the inside of the upper edge.

This description, along with police photographs, will convey an excellent impression of the wound at any future date, including at the trial, which may be many months later. The position of the injury is related to obvious anatomical points and the height above the ground may have relevance if the stature of the victim and assailant, and the angle of attack, become legal issues. On the scalp, the occiput and the tip of the ear can be used as reference points, together with the vertex and the centre line of the head. On the face, the obvious landmarks are the eyebrows, nasion (craniometric point where the top of the nose meets the ridge of the forehead), tip of nose, lips, point of chin and angle of jaw. Where large areas of abrasion or bruising are present, similar measurements of lesion size are needed, but more general descriptions of position may be sufficient, such as 'covering the external aspect of the left thigh' or 'extensive bruising 23 cm by 18 cm on the right side of the chest extending from axilla to costal margin'.

Where widespread burns are present, an estimate of the total area using the 'Rule of Nines' should be made, as described in Chapter 11.[41–43]

Other injuries, such as firearm wounds, are described in the same manner, being careful not to clean off any powder residues or other trace evidence before the forensic scientists have collected their samples.

With head injuries, the scalp is examined in its original condition first and any trace evidence collected. Then any clotted blood that frequently obscures the injuries can be gently removed, using a sponge and water. After this stage has been studied, it is usually necessary to shave off hair carefully around the wounds, so that the full extent of the lacerations and especially the state of their margins can be assessed and photographed. This shaving is best carried out with a scalpel fitted with a new blade,

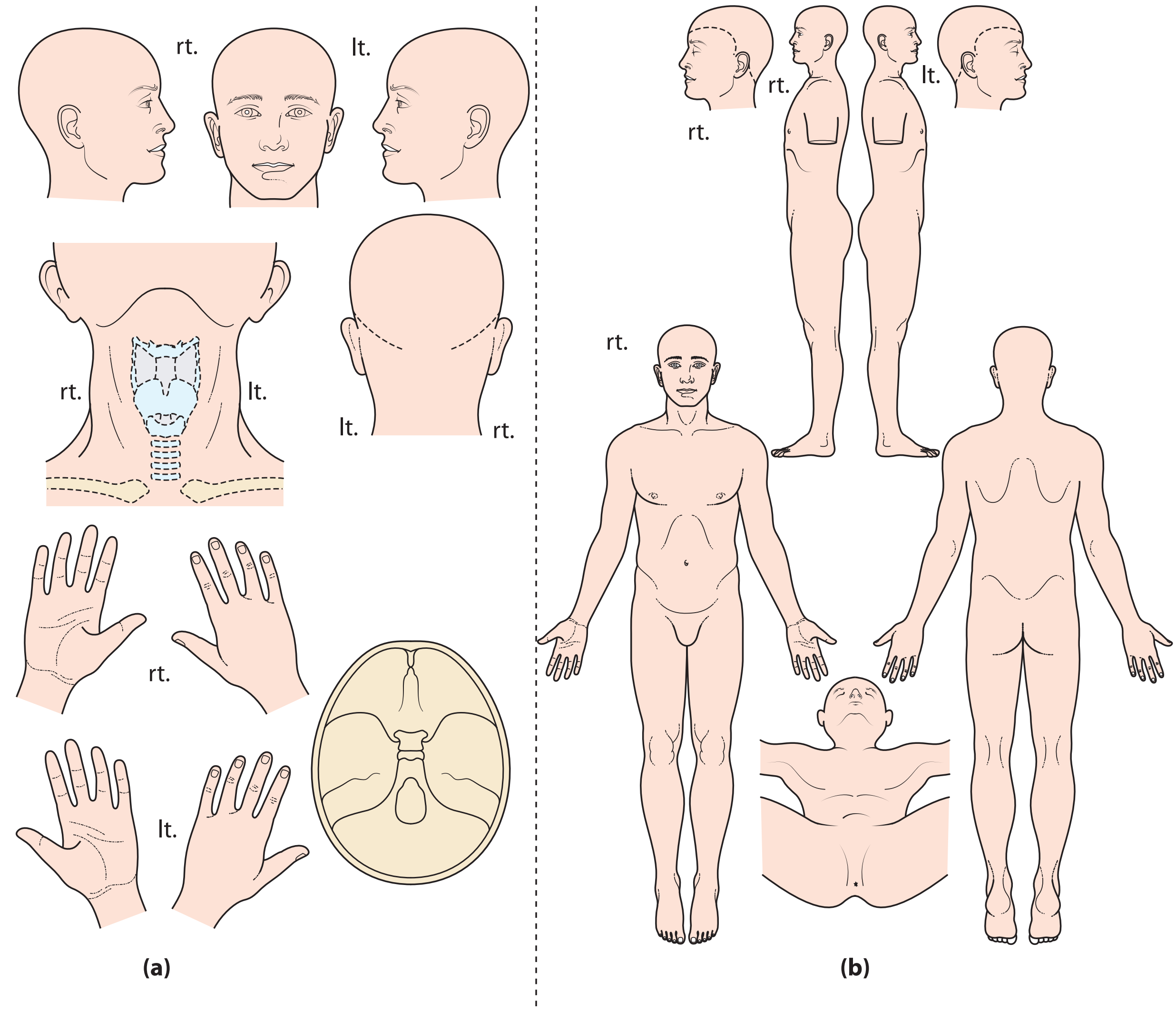

Figure 1.9 ***(a, b)*** Typical examples of the many anatomical diagrams available for the recording of external findings at autopsy.

Figure 1.10 Examination and photography of injuries; after full preliminary examination and forensic sampling the area is cleaned, shaved if necessary, and photographed with a scale adjacent to the injuries.

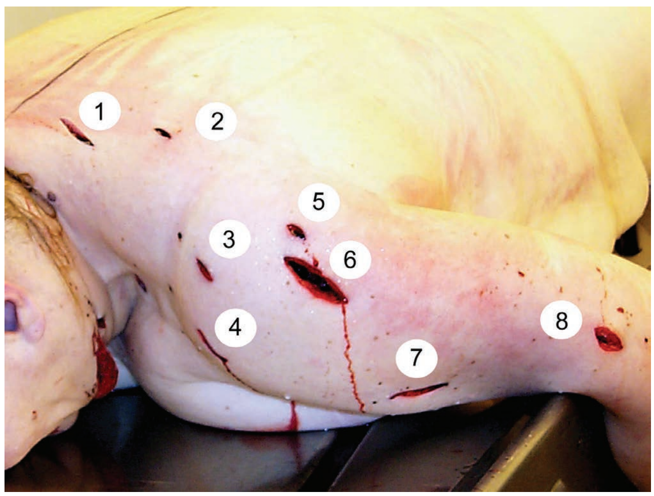

Figure 1.11 Where there are numerous similar lesions, it assists the clarity of the autopsy report if numbers used during photography match those listed in the autopsy protocol.

the blade being kept almost parallel with the surface to avoid making false cuts. The procedure should be carried out by the pathologist himself and not delegated to a mortuary technician. In this way any artefactual cuts can be recognized as such and not misinterpreted as part of the original wound.

- The eyes must be examined carefully, especially to detect petechial haemorrhages on the outside of the eyelids, conjunctivae and sclera. Though these do not necessarily indicate an asphyxial process, such petechiae require an explanation. Petechiae should also be sought behind the ears and in the skin of the face, especially around the mouth, chin and forehead. Care must be taken to differentiate these fine petechiae from the more coarse intradermal blood spots often seen across the shoulders or upper chest, which are caused by post-mortem hypostasis in a body with marked agonal venous congestion – especially when that surface of the body has been dependent (see Fig. 2.6). Haemorrhages in postural hypostasis are of no diagnostic significance, as true ante-mortem bleedings can never be differentiated from those that commonly develop after death.

  The size of the pupils is rarely useful, as rigor in the iris musculature can produce any degree of constriction, which may be unequal on either side (see Chapter 2). False eyes, contact lenses, lens opacity and other defects are to be noted. It is not possible to evaluate the degree of visual acuity during life from any type of post-mortem examination – though obviously a significant defect such as a cataract or a large vitreous haemorrhage is likely to affect vision.
- The mouth may reveal foreign bodies, drugs (Fig. 1.8), damaged teeth, injured gums and lips, and the bitten tongue of epilepsy or blows on the jaw. Dentures should be identified and removed before autopsy. Gastric contents in the mouth need not indicate ante-mortem regurgitation, as discussed in Chapter 14, but should be noted. Dried powder on the lips may suggest the recent taking of medicaments or poisons (see Fig. 31.1); corrosion of the mouth, lips and chin may be seen in irritant poisons (see Fig. 33.4). Bleeding from mouth, nostrils, or ears must be recorded, and later investigated as to source from internal examination. Frothy fluid, sometimes blood-tinged, may be seen issuing from the mouth or nostrils, or both, in drowning and from pulmonary oedema due to a variety of causes. Froth is sometimes pink or frankly blood-tinged. This has no particular significance unless gross, as in drowning, sudden infant death and other conditions with marked pulmonary oedema; rupture of small pulmonary or even pharyngeal vessels can add a little blood to colour the foam.
- The external genitals require careful examination, as does the anus. The state of the latter can be misleading, as a widely open, patulous anus is often seen post-mortem, due to flaccidity of the sphincter. The inner mucosa is often visible through the orifice. This is also the case in infants and children, and a diagnosis of sexual abuse must not be assumed without other corroborative evidence such as fresh mucosal tears or swabs positive for semen.

The 'funnel-shaped' anus, beloved of traditional textbooks as a sign of chronic homosexual activity, is such an extreme rarity that its true existence is doubtful. A funnel shape is a normal anatomical variant, the anus being set deeply between the buttocks, sometimes with a commissure of skin above it, making the approach seem even deeper. The alleged 'shiny, silvery hyperkeratinized skin of the habitual pederast' is also of little diagnostic value as scratching from chronic irritation, often associated with haemorrhoids, viral infections or threadworms, may lead to the same appearance. The only reliable criteria are fresh tears and old scars, as well as mucocutaneous eversion, though even these can arise from severe chronic constipation (see also Chapter 18).

Examination of the vulva and vagina is made to exclude obvious injury and disease, unless the nature of the case suggests some sexual interference, when a far more detailed examination and a special autopsy technique is carried out (Chapter 18). Routine examination of the male genitals usually need only extend to general inspection of the penis, glans and scrotum, with palpation of the testes. Circumcision should be noted, as (rarely) it may assist in identification.

The autopsy: internal examination

The dissection in a forensic case is basically similar to any other autopsy, with variations according to the nature of the death and the needs of the particular investigation, whether it be a criminal case, a civil dispute or an accident investigation. (Fig. 1.12)

There are a number of manuals devoted to the performance of an autopsy as well as one for the instruction of mortuary technicians.[44–47] Only an outline of the technique is offered here for those unaccustomed to examining the dead who may have autopsies thrust upon them by circumstances.

Figure 1.12 Scene of crime officers recovering trace evidence from hands before a homicide autopsy. The pathologist must offer the rest of the team every facility to complete their work before he begins his dissection.

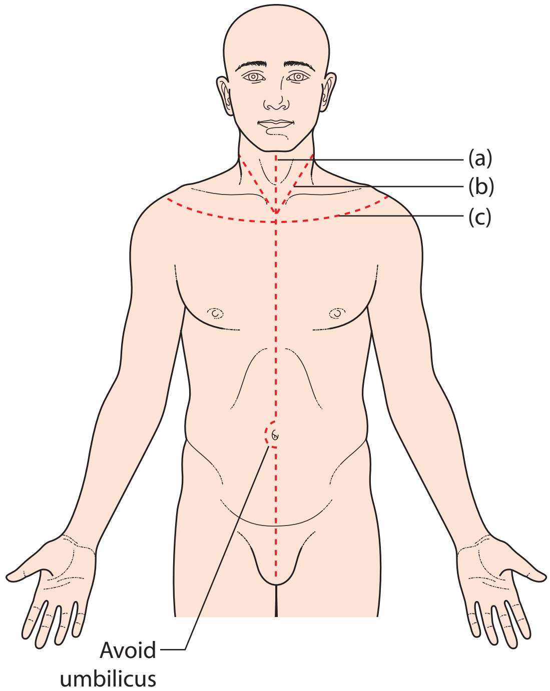

Figure 1.13 Autopsy incisions: (a) standard midlline; (b) 'V-shape'; and (c) subclavicular.

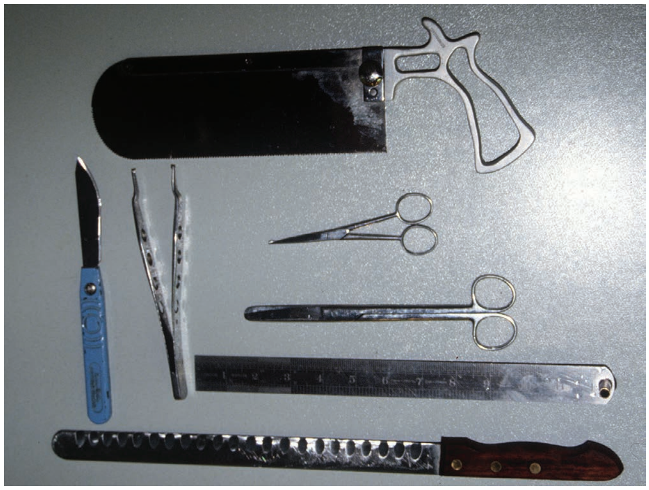

Figure 1.14 The minimum instruments needed for performing an autopsy. Any further items may be useful but not essential.

In addition, special forensic procedures are described, though these are also discussed in each of the chapters devoted to the various types of injury and death. The autopsy on infants is dealt with in Chapters 20–22.

The usual incision is an almost straight line from laryngeal prominence to pubis, deviating to avoid the umbilicus. The upper end of this incision should not be prolonged above the larynx, as even a high-necked shroud will then fail to hide the subsequent suture line from relatives (Figs 1.13, 1.14).

Another common method is to cut from behind each ear to a point above the manubrium and continue downwards in a 'Y-shape'. This is often done in infants and wherever it is desired to avoid disfiguring the front of the neck. In the USA in particular, the Y-incision is favoured or even a deep 'U-shape' carried across the upper chest.

In strangulation, hanging, and any condition where the larynx might be damaged, the Y-incision is to be preferred, as the skin of the upper neck can then be dissected off the mandible and raised clear to give a wide approach to the neck structures. Here, the incision should not be made until the skull-cap and brain have been removed, to avoid the congestive artefactual haemorrhages in the neck structures, described by Prinsloo and Gordon, which can be confused with true ante-mortem trauma.[48] Pollanen *et al.* developed a model, where uninjured human cadavers, with unfixed lividity, were placed prone on a wooden board and kept at an angle of approximately 25° with the anterior neck at the lowest point. The bodies were kept for 24 hours at room temperature (~22°C) and subsequently for an additional 24 hours refrigerated (4°C) in the same position. They reported that extensive hypostatic haemorrhages or haemorrhagic lividity could be reproducibly but not universally induced in the soft tissues of the anterior neck and strap muscles and that they were microscopically indistinguishable from the acute haemorrhages observed in contusions.[49] Gordon *et al.* have further suggested that the brain be removed first in all autopsies so that abnormal odours can be detected before being swamped by the smell from the opened abdominal cavity.[50]

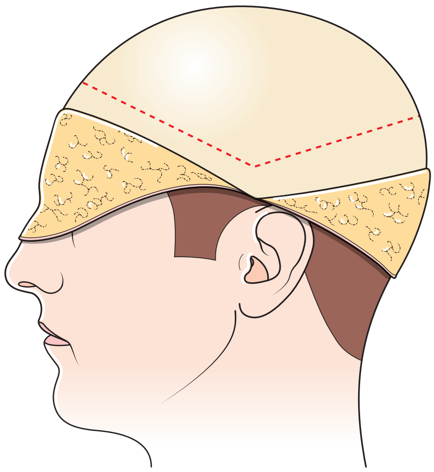

Figure 1.15 Angled saw-cuts for removal of skullcap to avoid slippage during reconstruction.

The Y-incision is also required when dissection of the face is necessary, to look for deep bruising or bony damage. In fact the whole face can be dissected off completely from the skull and replaced with little effect upon the cosmetic result, if careful dissection is employed. The Y-incision in the neck is made continuous with the transverse scalp incision, joining these behind each ear, so that the anterior neck and facial skin can be removed in entirety.

Returning to the autopsy in general, the primary incision should be shallow over the neck to avoid cutting underlying structures, especially the trachea. The thorax can be cut down to the sternum, but care must be taken over the abdomen, where a light cut is made, sufficient to incise only skin and fat. A small puncture should then be made in the peritoneum and a finger inserted to lift it away from the intestines. The knife is then used to cut outwards along the length of the abdomen, to avoid penetrating the intestines.

The incision for access to the skull is made from behind each ear, meeting over the crown of the head. It is well to keep this posterior to the actual vertex, again to make the stitching less obvious, especially where the hair is scanty or absent. With abundant hair – and especially in children – the hair should be wetted and then combed backwards and forwards from a transverse parting made in the line of the prospective incision. Hair is not then severed and can be combed back later to cover the stitching (Fig. 1.15).

Exposing the body cavities

The skin, subcutaneous tissues and fat are flayed off laterally from the main incision, taking care not to let the edge or point of the knife come through the skin, especially in the neck area, where repair can be unsightly. The tissues are taken back to the lateral edge of the neck and to the outer third of the clavicles. Over the thorax, the tissues, including pectoral muscles, are flayed off to the midaxillary line in the upper part and even further posteriorly towards the costal margin.

The anterior abdominal wall is similarly separated. This can be done either in two stages, first stripping back the skin and fat to expose the muscles – or the full thickness of skin, fat and muscle can be reflected together. The muscle must be cut from the costal margin and, if thick fat overlies, then some transverse relieving incisions can be made on the peritoneal surface of the lower abdominal wall, taking care not to come through to the skin.

Opening the thorax

If a pneumothorax has been suspected beforehand, a post-mortem radiograph (CT etc.) is the best confirmation. One can also dissect the intercostal space down to the parietal pleura and visualize the lung directly underneath and its collapse when incising the pleura with the tip of a scalpel. The presence of pleural adhesions must be considered. Alternatively, the chest wall can be punctured in the midaxillary line after filling the reflected skin with water to observe if bubbles escape. This test is rarely successful and cannot succeed if there is a patent communication between the pleural cavity and the bronchial tree. If there is a marked tension pneumothorax, the hiss of escaping air may be heard when the tip of the knife penetrates the intercostal muscles and parietal pleura.

The thorax is opened by first disarticulating both sternoclavicular joints. This is carried out by moving the shoulder tip with one hand, to identify the joint capsules. The point of a knife is then introduced vertically and cut laterally in a half-circle to separate the joints. If they are ankylosed, which often occurs in old age, then the clavicles can be cut through at the end of the next operation. This consists of the severing of the ribs and can be performed either with a handsaw or a rib shears. In children and many adults, the costal cartilages may be cut through with a knife, though this provides a rather narrow exposure of the chest contents. In infants, the soft cartilage can easily be divided with a scalpel: in older bodies, a stout knife should be kept for the purpose to save blunting the knife that is needed for organ dissection. Often the first rib has to be sawn through, even though the remainder are cut with a knife.

When a saw is used, the ribs are cut through lateral to the costochondral junctions from a point on the costal margin to the sternoclavicular joints or nearby. If a saw is used, it must be kept at a low angle to avoid the tip lacerating the underlying lung, especially if there are pleural adhesions. When the sternum and medial rib segments are free, the section is lifted and dissected away from the mediastinum, keeping the knife close to the bone to avoid cutting the pericardium. The sternal plate is examined for fractures or other lesions before it is put aside: damage caused by the considerable trauma of resuscitatory cardiac massage is frequently found at this point.

The whole of the thorax and abdomen is now open for inspection. The degree of inflation of the lungs should be assessed, noting complete or partial collapse, emphysema, overdistension and any asymmetry of inflation.

The pleural cavities are inspected for adhesions, effusions, pus, blood, fibrin and even gastric contents.

Examining the abdomen

The abdomen is then inspected (Fig. 1.16), though ascites, faeculent fluid, pus and blood may already have escaped on first opening the peritoneal cavity.

The omentum may show inflammation or fat necrosis. When moved aside, the loops of bowel are inspected for any abnormality, especially infarction, peritonitis and the distension of ileus. Beware of mistaking post-mortem hypostasis for the necrosis of mesenteric embolism or strangulated bowel. Though the dark colour may be similar, hypostasis usually has irregular segments when the gut is stretched out, whereas infarction occupies one continuous section – and if well established, the bowel wall will be lustreless and friable.

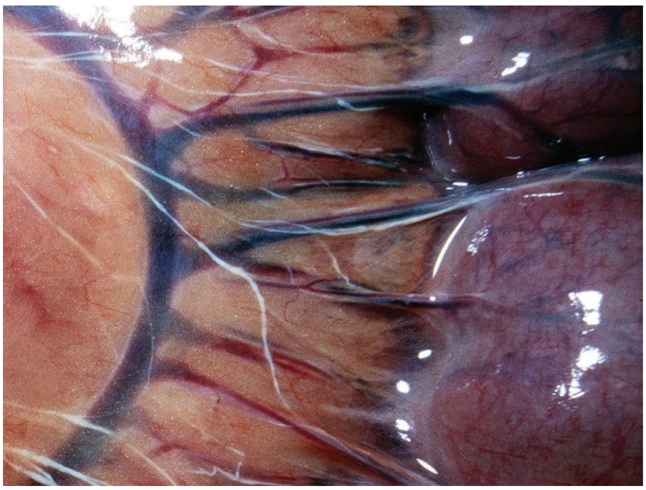

Figure 1.16 White shining fat droplets (chylomicrons) in mesenterial lymphatic vessels suggesting post-prandial state.

The bowel is gently moved aside to look at the posterior part of the abdomen: a retroperitoneal haemorrhage from a ruptured aorta may be visible, or an aneurysm itself.

The collection of body fluid samples

In a large proportion of forensic autopsies and virtually every one with criminal connotations, samples of blood and other body fluids and tissues are needed for laboratory examination. In relation to sexual offences, the taking of swabs and other samples is described in Chapter 18. Where blood and other fluids are required for toxicological, biochemical, microbiological and serological investigations, they are usually collected at the early stages of the autopsy (see Chapter 27).

The site of collection depends on the nature of the test. When samples for toxicological analysis are required, considerable care should be employed in sampling; this is more fully discussed in Chapter 27.

It is not advisable to use visceral blood for sampling, especially for small molecule substances that can easily diffuse after death; these include alcohol and many pharmaceutical products. Though older textbooks advocate the use of heart blood as a convenient source of samples, it may be contaminated by post-mortem diffusion from the stomach and intestine. After death, the cellular barrier of mucosa and serous membranes breaks down, and substances in the stomach, intestine and air passages can migrate to other organs in the main thoracoabdominal cavity, causing a false rise of the true ante-mortem blood level.

Pounder and Yonemitsu (see Chapter 27) found that a slurry containing alcohol and paracetamol, placed in the trachea after death to resemble gastric contents, gave rise to appreciable concentrations of those substances in blood samples taken from thoracic vessels, whereas femoral blood remained uncontaminated.[51]

For substances such as carboxyhaemoglobin this does not matter, but alcohol is the prime example of a potential source of error if visceral blood is collected. The better choices for collection sites are:

- By needle and syringe puncture of the femoral vein before the autopsy dissection begins. This requires practice but, in adults, 20 ml can usually be aspirated without trouble. This is the method of choice if only an external examination is possible.
- From the subclavian or external iliac veins after the body has been eviscerated. By holding a small container under the cut end of a subclavian vein and raising the arm, blood can be collected directly.

If the flow is slow, the arm can be massaged towards the shoulder. Similarly – and preferably if volume is required – by cutting across the iliac veins at the brim of the pelvis, a container can be dropped into the pelvis with its mouth under the vein and blood massaged into it by firm pressure moved up the inner thigh. As all these containers will be soiled externally, the blood should be decanted into a fresh tube for transmission to the laboratory.

- When the skin is dissected off the neck, the internal jugular vein is exposed, especially if a sternomastoid muscle is divided and pulled aside. When cut, a copious flow of blood is usually obtained, which can be collected directly into a container. The only disadvantage of this method is that if the blood wells up from the thoracic inlet via the superior vena cava, heart blood is likely to be admixed, with the possible errors mentioned earlier. If the blood is collected from the upper segment of the jugular, then blood from the head is collected: this flow can usually be stimulated by raising and lowering the head during collection.

Samples for serology and for analysis for substances such as carboxyhaemoglobin, which are not absorbed from the gastrointestinal tract, can be collected from any blood vessel, but blood should never be scooped up from the general body cavity after evisceration, as this can be contaminated with any leakage from other structures, such as gastric or bowel contents, mucus, urine, pus or serous fluids.

Urine can be collected by catheter before autopsy or even by suprapubic puncture with a syringe and long needle. However, it is usually obtained after the abdomen is opened, but before the organs are removed. If the bladder is full, the fundus is penetrated, and urine collected either by syringe or directly into a container. If almost empty and contracted, the fundus is gripped and pulled upwards so that it stretches, then is incised and the contents removed by syringe. Care should be taken not to contaminate the urine with blood.

The removal of vitreous humour and CSF may be required for toxicology or for attempts at estimating the time since death by the potassium content (see Chapter 2). Vitreous humour must be aspirated with care if any reliable results are to be attained. A fine hypodermic needle attached to a 5 ml syringe is inserted into the outer canthus of the globe after pulling the eyelid aside. When released, the lid will cover the small puncture mark, hiding any sign of interference. The needle should be entered into the centre of the globe to avoid aspirating material near the retina, which has a markedly different chemical composition due to shreds of detached retina entering the aspirate. The fluid should be sucked off slowly and gently, and as much taken as possible to obtain a mixed fluid: both eyes should be used, as they often differ somewhat in their chemical composition. After withdrawing vitreous, the globes can be re-inflated with water, to improve the cosmetic appearance of the eyes.

Cerebrospinal fluid may be obtained in the same way as in living patients, by passing a needle into the theca between the lumbar spines. A baby can be held upright by an assistant in a fully flexed position; an adult must be pulled into flexion while lying sideways on the autopsy table. An alternative technique is to perform a cisternal puncture through the atlanto-occipital membrane.

As there is no pressure within the theca in a cadaver, the fluid must be actively aspirated: sometimes all attempts at obtaining fluid by external puncture fail. The only course then is to try to puncture the ventricles through the exposed brain surface when the skull is opened. Attempting to obtain clear CSF from the interior of the skull after removal of the brain is generally useless: though blood-stained fluid can be centrifuged to clarity, its chemical composition is then unreliable.

Removal of the viscera

After the body cavities have been inspected, the organs are removed *en bloc* by a modified Rokitansky procedure, more accurately described as Letulle's method (Maurice Letulle, 1853–1929). First, the intestine is removed, as follows.

The omentum is lifted upwards to expose the coils of small intestine. The uppermost part of the jejunum is identified, where it passes retroperitoneally to join the termination of the duodenum. Here the mesentery is perforated with the knife and the gut cut through. If it is essential to retain the duodenal/gastric contents or the small intestinal contents, two string sutures may be passed through the hole and tied before cutting the gut between them, but little contents are lost if this is not done. The intestine is stripped out by cutting along the mesentery near the attachment with the bowel until the ileocaecal valve is reached.

The caecum is then mobilized medially using manual traction with minimum use of the knife, to avoid puncturing the lumen. When the hepatic flexure is reached, the omentum is pulled downwards to draw the transverse colon tense against the mesocolon, which is cut through, taking care not to open the adjacent stomach. The splenic flexure is then pulled medially and downwards, and the descending and sigmoid colon separated from the posterior abdominal wall. The upper rectum is cut across, though some pathologists merely lay the gut outside the body, leaving the sigmoid and rectum attached.

Removing the neck structures

To make the removal of the neck structures easier, a block 10–15 cm high should be placed under the shoulders of the cadaver. This allows the head to fall back and thus extends the neck. This should be done gently, as with all handling of the body, to avoid the well-known 'undertaker's fracture', which is a subluxation of the lower cervical spine due to tearing of the intervertebral disc at about C6–C7. This can be misinterpreted as an ante-mortem injury, especially if the other common artefact of haemorrhage over the anterior longitudinal ligament of the cervical spine is present.[48] The neck structures are then freed by passing a knife under the skin of the upper neck until it enters the floor of the mouth. The knife is then run around the inside of the mandible to free the tongue. The tissues at the back and sides of the pharynx are divided, and the tonsillar area cut through. Fingers are then passed up behind the mandibular symphysis to grasp the tongue, which is then drawn down, the remaining tissues behind the larynx being divided to release the neck structures. This should be done as far lateral as possible, so that the carotids can be removed with the laryngeal structures. It is now advisable to look into the pharynx and glottis before any further disturbance, to see if any obstruction, bleeding or other abnormality is present in the upper airway.

Removal of the thoracic contents

The subclavian bundles of vessels and nerves are divided by passing the knife from inside the thorax around the medial ends of the clavicles and first ribs to release the trachea and oesophagus. With gentle traction, the neck structures are held up and pulled caudally, while carefully clearing all attachments to the thoracic spine with the knife, taking care to keep the blade on the bone and not stray anteriorly to damage oesophagus or aorta.

Traction should be minimal and, as soon as the thorax is entered, the hand should move from the neck structures to place two fingers under the upper lobes of the lungs, lifting them and the mediastinum as the knife clears the midline structures down to the diaphragm. If the neck structures are pulled too hard by using them as a handle to drag out the thoracic viscera, they may be ripped off. In addition, the descending aorta may suffer transverse intimal tears from traction, which resemble the genuine 'ladder tears' seen in many traffic accidents (Chapter 9).

Pleural adhesions may prevent clean removal of the lungs. If there are only a few, they can be cut through. If the whole pleural cavity is obliterated by adhesions, they may be pulled away by making a cleavage plane with the hand and stripping them off. Sometimes (especially in industrial chest disease and old tuberculosis) the adhesions are dense, tough or even calcified. Removal of the lung may then be achieved by running a knife down the whole length of the parietal pleura over the inner anterior aspect of the ribs, and forcing a hand through the slit to form a cleavage plane to force the parietal pleura off the intercostal muscles and ribs.

Removal of the abdominal organs

When the chest organs are free, they are laid back in the thorax and the diaphragm incised. One hand should pull the liver and spleen medially, putting the left leaf of the diaphragm on the stretch, while the knife cuts it through laterally, near the costal margin. The cut curves posteriorly under the organs to reach the spine, where it must cut through the cruciate ligaments, then passes caudally behind the kidney, which is mobilized forwards.

The knife cut then curves up over the psoas muscle and ends at the brim of the pelvis. The same is done on the opposite side, the operator moving around the body if necessary. The chest organs are then lifted and gently pulled forwards to carry the abdominal viscera towards the feet. Any resistance is usually due to incompletely severed cruciate ligaments, which must be transected.

Eventually the organs will lay inverted across the pubis, secured only by the iliac vessels and ureters, which are cut through and the whole pluck of viscera taken away to the dissecting bench where running water and good illumination must be available.

Removal of the pelvic organs

The treatment of the pelvic contents depends on the type of case. Where the presumed cause of death is unrelated to pelvic lesions, then in males the bladder may be opened widely and the mucosa and trigone inspected before the prostate is incised for examination. The testes are pushed upwards through the inguinal canals, which are widened with the knife. In women, the ovaries are incised and the tubes examined from above before the uterus is sliced in the midline from fundus to cervix.

A more thorough examination of either gender may be made by enucleating the pelvic contents. The knife is passed circumferentially around the pelvic bowl after pulling the bladder away from the pubis. When the walls are free, the knife cuts through below the prostate and then through the lower rectum to allow the pelvic organs to be lifted out. In women the ovaries and tubes are mobilized forwards and the knife passed around the wall of the pelvic bowl, then in front of and below the bladder. The vault of the vagina and rectum is transected, freeing the whole contents. In cases where sexual interference or abortion is suspected, a special technique described in Chapter 19 is employed.

Removing the brain

Attention is then turned to the head. The scalp is incised across the posterior vertex from a point behind the ear to the corresponding place on the other side. Where a Y-incision is used on the neck, the limbs of the Y may be continued right across the scalp, especially if a face dissection is necessary.

The tissues are reflected forwards to the lower forehead and back to the occiput. The deep scalp tissues may peel off by traction, but often require touches of the knife to free them. Bruising is sought and, where head injuries are present or suspected, the scalp should be reflected right back to the nape of the neck, paying particular attention to the tissue behind and below each ear where injuries causing vertebrobasilar artery damage occur. Where there are facial injuries, the skin of the face may be peeled back from the jaw line and downwards from the forehead, restoration being excellent if care is taken not to perforate the facial skin during removal.

The skull is sawn through, using either hand or power tools. The line of the cut should not be along a circumference, as it is then impossible to reconstitute the head without unsightly sliding of the calvarium. There should be an angled removal, with a horizontal cut from forehead to behind the ears joined by a second, which passes diagonally upwards at a shallow angle over the occipitoparietal area. Care must be taken not to place this posterior saw-cut too vertically (and thus anteriorly) on the skull, or the brain may be damaged by forcing its removal through too narrow an aperture.

The calvarium is then removed by leverage after complete cutting through. A mallet and chisel should not be used in forensic autopsies, even to ensure that the dura is kept intact. The risk of extending or even causing fractures by the use of excessive hammering is too great merely to justify an unmarked dural membrane. A cut dura is easily recognized as such by any competent pathologist. What is more important is to inspect the surface of the exposed dura and brain and assess any oedema, bleeding or inflammatory conditions that may be present. The skull-cap is carefully inspected for fractures and the dura peeled off the inside to study the inner skull surface.

To remove the brain, the dura is incised around the line of skull removal and two fingers slipped beneath each frontal lobe. With gentle traction the frontal lobes are lifted to expose the optic chiasma and anterior cranial nerves. The falx may have to be cut to free the brain, then a scalpel or blunt-pointed bistoury is passed along the floor of the skull to divide the cranial nerves, carotid arteries and pituitary stalk until the free edges of the tentorium are accessible. A cut is made along each side of the tentorium, following the line of the petrous temporal bones to the lateral wall of the skull. Continuing with traction on the brain, but being careful not to impact the upper surface against the posterior saw-cut, the knife severs the remaining posterior cranial nerves and then passes down into the foramen magnum to transect the spinal cord as far down as can be reached. The hand is now slid under the base of the brain, which is rotated backwards for removal, any attached dura being severed where necessary. The brain is taken into a scale pan and weighed before either fixation or dissection.

The floor of the skull is now examined and the basal dura stripped out with a strong forceps to reveal any basal fractures. Discarded dental forceps can be useful for this purpose. The venous sinuses are incised to search for thrombosis. Where appropriate – and always in infants – the petrous temporal bones are sawn, chiselled or cut with bone forceps to examine the middle and inner ears for infection.

Removal and examination of the spinal cord

It is not an invariable routine to remove the spinal cord at autopsy unless there are indications that some lesion may be present. Where there is the slightest possibility of damage to the vertebral column, its blood vessels or the contents of the spinal canal, however, there should never be any hesitation in extending the autopsy to include this area.

There are several methods of removing the cord and for full details, the texts of Ludwig or Knight should be consulted.[45,47] Briefly, there are two main approaches to the spinal canal, the anterior and posterior.

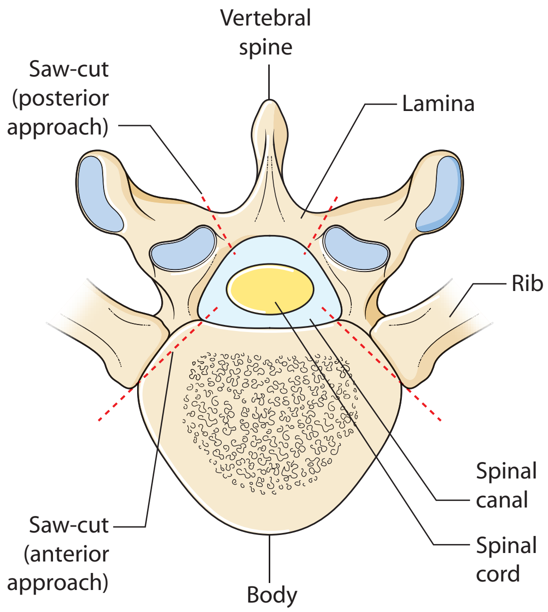

Figure 1.17 The two approaches to the spinal canal for the removal of the spinal cord at autopsy.

In the anterior method, the vertebral bodies are removed after complete evisceration of the body, by sawing through the pedicles by a lateral cut down each side. The advantages are that the body need not be turned over onto its face and an extensive dorsal incision is avoided, which requires subsequent repair. The author finds this method more laborious, however, especially in the thoracic region where the heads of the ribs make the approach difficult.

The more usual posterior approach requires a midline incision from occiput to lumbar region, the paraspinal muscles being reflected along with subcutaneous tissues. Two parallel saw-cuts are then made down the length of the spine to divide the right and left laminae, and to give access to the spinal canal. This is best done with an electric oscillating saw, taking care not to cut so deeply that the spinal dura is penetrated. The strip of bone may be dissected off from below upwards to expose the spinal canal (Fig. 1.17).

The cuts should be placed sufficiently lateral to allow the cord to be removed without difficulty. When the canal is exposed, the dura is examined for haemorrhage, infection or other abnormalities, then removed – still within its dural sheath – by transecting the nerve roots and dural attachments, and peeling it out progressively from below upwards. The dura is then carefully opened with forceps and scissors to examine the cord itself. It can be fixed in formalin, as with the brain, before cutting, or dissected immediately and samples taken for histology. Crushing, infarction, infection, haemorrhage and degeneration are the main lesions in a forensic context. The empty spinal canal must be carefully examined for disc protrusions, tumours, fractures, haemorrhage, dislocations and vertebral collapse.

Where in any autopsy spinal damage is suspected, a good preliminary test is to slide the hands under the back of the eviscerated body on the autopsy table and lift the dorsolumbar spine upwards, while watching the interior vertebral bodies. If a fracture or dislocation is present, abnormally acute angulation will be seen, instead of smooth bending. The cervical spine can be tested by manual manipulation. If suspicious angulation is seen, a slice can be taken along with the anterior spine, through the vertebral bodies and discs, with an electric or handsaw. This will reveal the interior of the spine and exhibit any crushing, haemorrhage or torn disc spaces: if one of these is found, the cord must always be removed.

Examination of organs

Examination of viscera

The thoracic and abdominal viscera are laid on a cutting bench at a convenient height and under good illumination. Ample washing water should be available from a flexible pipe, to flush the tissues as dissection proceeds. Some pathologists maintain that this should not be done, as the water can have an effect on the quality of subsequent histological sections, but this has been disproved.[52] In any case, the vastly inferior naked-eye examination that results if blood is not removed at frequent intervals greatly outweighs any unsubstantiated objections about the more exquisite details of cell structure, especially as in most forensic autopsies the gross appearances are usually far more important.

The viscera should be laid so that the tongue faces the pathologist, with the aorta upwards. The same sequence of examination should be carried out whatever the nature of the case, so that a fixed routine will ensure that nothing is left undone.

The neck structures

The tongue is examined for disease and injuries, including bites suggesting blows in the jaw or epilepsy. The tongue should be sliced to detect deep haemorrhages sometimes seen in strangulation. Such haemorrhage is seen mostly at the sides and centre of the midpart of the tongue. Gross congestion, which may be due to either pressure on the neck or to other congestive modes of death, is usually in the posterior part of the tongue. The tonsils and pharyngeal walls are inspected.

The glottis is examined for mechanical or infective obstruction, and the hyoid and thyroid horns palpated for fractures. The oesophagus is opened with large (20 cm) blunt-nosed scissors, which along with a very sharp 10–15 cm bladed knife and a long-bladed 'brain knife', are the most useful tools for performing an autopsy.

The carotid arteries on each side are opened, including the bifurcations and sinuses. If necessary, the upper portions of the carotids are explored in the body itself and followed to the base of the skull. If thrombosis is suspected, the intracranial part should be examined in the cavernous sinus.

Returning to the neck structures, the thyroid should be sliced and inspected, then the oesophagus opened almost to the cardia of the stomach and any suspect material such as capsules, tablets or powder retained for analysis.

The scissors are then passed down the posterior line of the larynx and trachea to the carina. If pressure on the neck of any type, such as strangulation, is suspected, then special examination should be made, as described in Chapter 14.

The trachea and main bronchi should be inspected for disease and obstruction. Gastric contents are often found, but the significance of this is discussed in Chapter 13 – it should not be assumed that ante-mortem aspiration has occurred merely from the presence of gastric contents in the air passages.

The lungs

The lungs are then removed, after careful examination of their external surfaces for patchy collapse, emphysema, petechiae and so on. Almost every autopsy will reveal a few petechiae, especially around the hilum and in the interlobar fissures. Their significance is also discussed in Chapter 13.

The lungs are removed from the thoracic pluck by passing a long-bladed knife (such as a brain knife) under the hilum with the blunt edge upwards. The knife is settled in the correct position before turning the sharp edge upwards to cut through the hilum. Before doing this it may be necessary to remove adhesions over the diaphragm and to cut through the pulmonary ligament, a thin sheet of tissue that ties the inferior medial edge of the lower lobe to the mediastinum.

As the hilum is being cut, the pathologist must notice if any embolism is visible within the pulmonary arteries. It has happened that such an embolism has slid out and been washed unnoticed down the sink. Some pathologists insist on opening the main pulmonary trunk and even right ventricle before removing the lungs, to seek a saddle embolus. This is not necessary, as any large embolus will be readily visible on examining the heart and the lungs in the usual sequence.

Both lungs are taken off and the hilum inspected before being laid aside for cutting. The lung should be weighed before cutting, as appreciable oedema fluid can run away during dissection. Then each is laid with the hilum down on the dissecting board, the opportunity being taken during handling to evaluate weight and oedema, as well as emphysema.

The lung is held on the upper surface by the left hand of the operator (or by an interposed sponge) and the organ cut across in the sagittal plane from apex to base with the large brain knife, held parallel to the board. This produces an anteroposterior slice, the lower medial part carrying the hilum. The cut surfaces can now be opened like a book and the surface examined for oedema, tumour, pneumonias, infarction, trauma and so on. The smaller bronchi must be inspected for such signs as mucosal thickening, infection and blockage. The smaller pulmonary arteries may reveal thrombosis or embolism that was not visible in the larger vessels.

Inflating the lungs with formalin

In some medico-legal autopsies, especially in industrial lung disease such as pneumoconiosis or asbestosis, one or both lungs need to be inflated with formalin for fixation before cutting. This preserves the shape and histology in excellent condition, but delays examination for at least several days. It is carried out by holding or tying a cannula into the bronchus while 10 per cent formol saline is perfused through a tube from a reservoir held about 1 metre above the lung. The lung is then left in a bath of formalin covered with a formalin-soaked cloth to prevent drying. Sutinen *et al.* described a post-mortem method for correlative radiological and pathological studies of the lung, including radiography after air inflation, fixation with formalin–polyethylene glycol–alcohol solution, air drying and systematic histological sampling of lung tissue.[53]

The heart and great vessels

There are almost as many ways of examining the heart as there are pathologists, and each operator must decide upon the method that appeals most. In this summary there is no space for discussion of post-mortem angiography, which is moving from the field of research and special interest into routine use. A common and practical routine for examining the heart is described here.

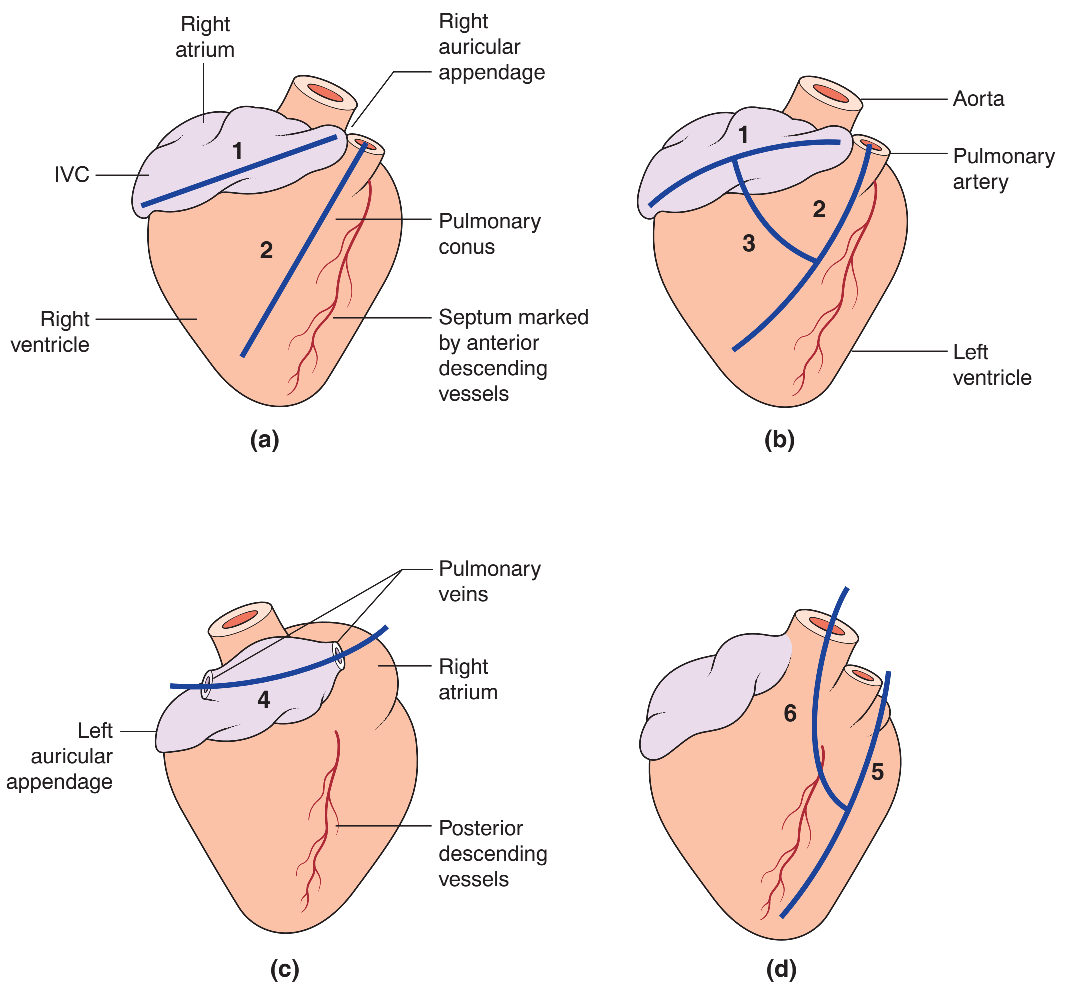

Figure 1.18 Incisions for opening the heart at autopsy. (**a**) The right atrium is slit with an incision (1) to join the vena cava to the appendage; a cut parallel to the interventricular septum is made on the anterior wall of the right ventricle (2) passing up through the pulmonary conus. (**b**) These cuts are joined through the tricuspid valve (3). (**c**) The heart is reversed and the left atrium opened by a cut (4) joining pulmonary veins. (**d**) On the anterior wall a cut (5) is made parallel to the septum through the mitral valve and joined by (6), which passes through the aortic valve.

First, the organ mass minus the lungs is rotated so that the lower end now faces the pathologist. The scissors are passed into the cut end of a common iliac artery and passed right up to the aortic arch and around to a few centimetres above the aortic valve, staying outside the reflection of the pericardium. The interior of the aorta is studied, especially for the degree of atheroma and for any aneurysms or trauma. The inferior vena cava is opened from its lower end into the liver. The organ pluck is then turned over so that the heart is uppermost. The pericardium is inspected externally for fluid and blood tamponade, then opened widely with scissors. The heart is delivered through the incision and inspected externally for pericarditis, adhesions, discolouration of an underlying infarct and cardiac aneurysms, for example. In a child, the thymus would be inspected and dissected off at this stage.

The heart is then removed by holding it up with the left hand so that its attachment is tensed against the other organs. A long knife, such as a brain knife, is then passed horizontally across at the reflection of the pericardium, cutting through the root of the aorta and other great vessels just above the atria.

The now-detached heart is washed externally and placed in the anatomical position on the dissecting board, with the apex facing the operator and the anterior surface upwards. It should not be weighed until all the contained blood and clot is removed. The general size, shape and ventricular preponderance should be noted. Any dilatation or thickening of the pulmonary conus should be noted as an index of right ventricular hypertrophy, especially if striae of transverse muscle fibres are seen crossing the conus.

The right atrium is then opened by introducing the scissors into the inferior vena cava and cutting across to the atrial appendage. The interior of the atrium is examined and the septum and tricuspid valve inspected (Fig. 1.18).

The interventricular septum is then identified externally by the vessels running down the outside. With a knife a cut is made about 15 mm to the right of and parallel to the septum, over the right ventricle. This should be deep enough to enter the lumen, but not enough to cut the posterior wall. The scissors are now introduced into the cut and run up through the pulmonary conus and into the pulmonary artery until they meet the transected end. They are also extended downwards to the apex of the ventricle. The scissors are now put in midway down this linear cut and passed outwards at right angles, guided by the fingers of the left hand passed into the tricuspid valve from the opened atrium. The whole of the right side of heart is now open and displayed. It should be washed out and the endocardium and valve examined.

A similar routine is now employed on the left side. The scissors are introduced into a pulmonary vein and passed horizontally across to an opposite vein, thus opening the atrium. Fingers are introduced down through the mitral valve to estimate its size and detect any stenosis.

The heart is then restored to the anatomical position and a cut made again parallel to the septum, but on the left side, going deeper as the ventricle is thicker. Guided by the fingers still in the mitral valve, the cut is extended upwards through that valve and out at the top of the atrium.

A finger is now passed up the outflow tract to the aortic valve to estimate its size. Then the scissors are passed up at the side of the mitral valve, and the aortic valve and aortic stump opened. The whole heart is now open and can be washed out and weighed.

Various estimates of the normal heart weight exist and vary considerably. It has been related to gender and body weight, though this is not altogether sound, as a fat person of moderate stature does not have a heart weight comparable with a large muscular person unless there is associated hypertension. This controversial matter cannot be pursued here, but as a rule of thumb the author (BK) accepts up to 380 g as normal in an adult male of average build.

After weighing, the endocardium and valves are examined, then the coronary arteries. Once again, controversy exists about methods of opening the coronary vessels, but the weight of opinion now lies almost universally with those who cut serial interrupted cross-sections with a knife, rather than open them longitudinally with small scissors. The disadvantages of lengthwise opening are that percentage assessment of stenosis or the recognition of total occlusion cannot be made once the vessel is flapped open, as restoring the cut edges can never reproduce the original conditions. In addition, the tip of the scissors may dislodge thrombus or an intimal flap. Cutting across the vessels allows an estimate of the percentage stenosis. It is admitted that this may not be the size of the lumen during life when normal blood pressure is operating, but the same disadvantage applies to longitudinal opening. An estimate of luminal size is relatively constant, however, in that the collapsed abnormal can still be compared with the collapsed normal.

The coronaries are therefore cut across at frequent intervals. Before the first cut, the ostia are examined for congenital variations (which are frequent) and for obstruction. The left coronary artery is then cut across from the epicardial surface, starting as close to the ostium as possible, as occlusion and severe stenosis can occur very near the origin. Serial cuts are then made at intervals of not more than 3 mm, first into the common trunk, then following the left circumflex laterally until the vessel becomes too small, usually when it dips down from the epicardium to become intramuscular. The anterior descending branch is then followed down the front of the septum almost to the apex.

Turning to the right coronary artery, the proximal segment is cut back from the point where the right ventricle was opened, transecting the artery in its midpart. The cuts are made back to the aorta, then the distal segment is followed laterally until it becomes the posterior descending branch. During this process, the dominance of right versus left vessels is noted.

Difficulty arises where severe calcification exists, as the knife either fails to cut through the artery or shatters it because of the excessive force required. The lumen is crushed and the percentage stenosis is difficult or impossible to assess. Scissors may be used to exert more force than a knife, but the only real solution is to decalcify the vessels. Except for research purposes, it must be admitted that the days or even weeks of delay occasioned by decalcification provide a formidable deterrent for the busy coroner's pathologist unless the issues involved are important. Post-mortem angiography is the other alternative, though where autopsy caseloads are high, this can be difficult to arrange. During autopsy, a contrast medium, such as barium sulphate/gelatin suspension or radio-opaque silicone compound is injected into the coronary arteries while the heart is *in situ* or into the vessels of the isolated heart and can be visualized by conventional or digital X-ray or by computed tomography.[54–56]

Once the coronary arteries have been examined, the myocardium can be studied more closely. One useful technique is the intramural or 'sandwich' cut through the thickness of the left ventricle. This is easier when there is some ventricular hypertrophy, but can be carried out in any heart. The heart is placed open on the cutting board, with the endocardium downwards. A long knife such as a brain knife is passed carefully into the cut edge of the left ventricle and sliced right through the muscle, keeping equidistant between endocardium and epicardium. The myocardium can then be opened out like a book, showing the interior with any infarcts or fibrotic plaques. If histological blocks through the entire wall are needed it is best to take these before slicing the heart as described, otherwise a full-thickness block will be hard to obtain. Some pathologists make a series of transverse heart slices about 8–10 mm thick, starting at the apex, before opening the heart. This displays the distal myocardium wall, but cannot expose the proximal part, as examination of the coronary arteries would then be compromised.

Figure 1.19 Collecting stomach contents at autopsy. The exterior of the stomach is washed free from blood and the viscera moved to overhang the dissecting board. A chemically clean receptacle is held beneath the greater curvature while the latter is opened with scissors and the contents allowed to drain out. The stomach is then opened, the mucosa inspected and any adherent material scraped into the container. The stomach wall should then be dissected off and added to the contents if the laboratory is able to deal with tissue analysis.

The abdominal organs

The remaining organs are laid on the dissecting surface in the anatomical position, with the liver and stomach away from the pathologist, and the anterior surface upwards.

The stomach is opened and, if there is any question of requiring the contents for analysis, a suitable container should be ready. The stomach is washed externally with a stream of water and a small cut made in the greater curvature. If the contents are to be saved, this can best be done with the edge of the stomach projecting over the raised cutting board or over the edge of the sink, so that the container can be held underneath (Fig. 1.19). The contents are allowed to run into the container, then the greater curvature is opened widely with scissors, and any remaining contents drained or scraped out. If powder or other substance is adherent to the mucosa, this can be scraped off and added to the container, or kept in a separate tube for analysis.

Some laboratories require the stomach wall to be retained for analysis as well as the contents. This can be done after the organ has been fully opened and the lining examined. If the contents are not required – or when they have been collected – the organ is opened up from cardia to pylorus along the greater curvature. The lining is washed and inspected. The scissors are now passed through the pylorus around the duodenum until they meet the point where the gut was detached earlier. The gall bladder may be squeezed to demonstrate the patency of the bile ducts. Bile is an important matrix for toxicological analysis, in particular, if there is no urine. The adrenals are examined next, the right one being on top of its kidney, the left being on the medial side. If the right kidney is taken in the left hand and lifted against the weight of the liver, a single cut into the stretched tissues between liver and kidney will transect the adrenal. The left is buried in the tissue between pancreas, spleen and kidney. The amount of cortical lipoid and the absence of bleeding or other abnormality is noted in each gland.

The spleen is removed by cutting through its pedicle and is sliced after weighing. The pancreas lies under the stomach and should be cut lengthwise from the curve of the duodenum to its tail lying against the splenic hilum.

The kidneys are exposed by incising their capsules, often after a thick layer of perirenal fat is traversed. The kidneys can usually be peeled out of their capsules unless these are adherent.

The renal vessels were examined when the aorta was opened, but can be re-examined at this stage and the ureters inspected. The organs can be detached at their hilum and weighed, then cut lengthwise to inspect the interior. The width of the cortex is important, being about 1 cm in a healthy subject. The granularity of the surface and the clarity of the corticomedullary junctions is assessed, as well as the size of the renal pelvis.

The small intestine may have been examined at the earlier stage of removal, but can be inspected now. It is not usual to open the whole length of the gut in a forensic autopsy unless there is any particular indication to do so, though ideally this should always be carried out.

Examination of the brain

After weighing, a decision has to be made whether to examine the brain immediately – the so-called 'wet-cutting' – or to suspend it in formalin until fixed. The advantage of fixation is, of course, that the firmness of the tissue allows thinner and more accurate knife-cut sections to be taken, as well as better histological preservation. Where neurological issues are involved, either traumatic or from natural disease, it is almost mandatory for the brain to be fixed before cutting. Even the impatience of the investigative authorities can usually be overcome if the advantages of a higher standard of opinion are explained.

The technique of brain fixation is well known, but to summarize briefly, the brain is suspended in a container of 10 per cent buffered formalin, the volume being about 10 litres, for at least 10–14 days. The fixative ought to be changed after 48 hours and 10 days.[57] The brain is removed with the dura, leaving the parasagittal bridging veins and falx intact and suspending the brain in an upright position by the falx (Fig. 1.21). An alternative method is to pass a thread or metal paperclip under the basilar artery and tie it to a support across the mouth of the container, so that the vertex is clear of the bottom (Fig. 1.20).

In the majority of autopsies there is no real need for fixation if no cerebral lesions are either expected or apparent on external examination of the brain. Here, 'wet-cutting' is sufficient, though if any unexpected lesions are found, the process can be stopped and the slices of brain fixed by placing them in a large volume of formalin, on cotton wool pads, to prevent distortion.

One lesion is better examined in the unfixed state, though the brain may be suspended later: this is subarachnoid haemorrhage. It is easier to wash away fresh, unfixed blood with a stream of water and blunt dissection than the hardened blood that develops during formalin fixation. Further details are given in Chapters 5 and 25.

Whether the brain is examined 'wet' or fixed, the sequence is the same. The weight is first considered, the normal for a young male adult being between about 1300 and 1450 g, the female equivalent being around 100 g less. It should be noted that formalin fixation adds about 8 per cent to the original weight.

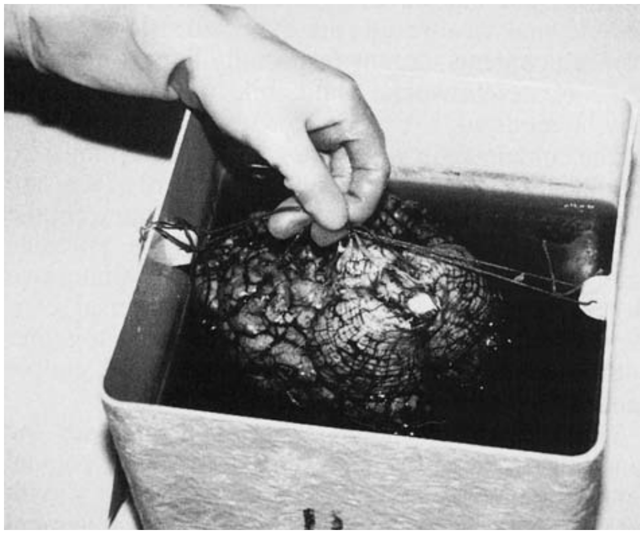

Figure 1.20 A brain suspended in formalin for fixation before cutting. The tank is specially made of fibreglass, being cubical for stacking with a lid (not shown). There are lugs moulded into the sides to hold the suspensory strings, which support the brain by means of a paperclip hooked under the basilar artery. There should be sufficient fluid to allow the brain to float clear of the bottom of the receptacle.

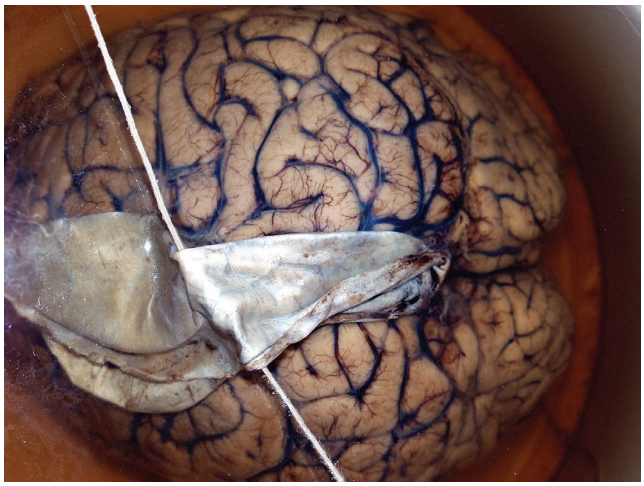

Figure 1.21 An alternative method of suspension is to leave the falx intact and use it to suspend the brain base down in formalin.

The brain is first examined for surface abnormalities, which in forensic practice usually means haemorrhage. This is dealt with in Chapter 5, but suffice to say here that meningeal bleeding is one of the most important lesions in forensic pathology, be it extradural, subdural or subarachnoid. This means that examination of the cerebral vessels, especially the arteries of the circle of Willis and the vertebral vessels, is vital – especially in the search for berry aneurysms (see Fig. 5.38). The general symmetry of the brain is then noted as well as any depression of the cortex from skull or meningeal masses. An estimate of cerebral oedema is made, partly from the weight, but mainly from flattening of the gyri, filling of the sulci and evidence of hippocampal herniation through the tentorial aperture. In lesser degree this may be seen as grooving of one or both unci, though a normal slight anatomical groove is often present. True uncal herniation is marked and often discoloured as a result of incipient infarction. Similarly, herniation or coning of the cerebellar tonsils through the foramen magnum must be distinguished from the common anatomical pouting of many tonsils: true pressure coning is often discoloured by local infarction (see Figs 5.48–5.50). After careful inspection of the basal vessels and the exterior of the brain, and palpation for any fluctuant masses under the cortex such as internal haemorrhage, abscesses or cystic tumours, the organ is cut.

The first cut should be made through the cerebral peduncles using a long, broad-bladed knife to separate the cerebrum from the brainstem and cerebellum. The cerebellum is then held in one hand with the cut stem upwards. This is examined to assess the substantia nigra and aqueduct, as well as to note any primary or secondary haemorrhage, the latter often being due to raised intracranial pressure. The cerebellum and pons are then cut down vertically and opened like a book to display the fourth ventricle, dentate nuclei and the interior of the cerebellum. The lower pons and medulla can be further sectioned transversely or longitudinally.

The cerebral hemispheres are then placed base down on the cutting block and serial sections made in the coronal plane from the frontal lobes back to the occiput. The sections should be about 1 cm thick and each should be slid into a sequential place in rows along the cutting board so that orientation is preserved. Cuts should be made with careful but bold sweeps of the knife as erratic sawing motions will leave an irregular surface on each section, which obscures a good view. Cutting a fresh brain is less satisfactory than cutting a firmer fixed brain, especially if there is any post-mortem autolysis or softening as in a dead ischaemic brain after mechanical ventilation.

Ancillary investigations

A wide range of samples may need to be taken either before, during or after the gross examination is completed. The nature of such ancillary investigations naturally depends upon the nature of the death, the history and the interests of the pathologist.

Microbiology

Though more common in clinical autopsies than forensic work, culture samples for ‘bacteriology’, virology and (rarely) fungi may be needed. For post-mortem bacteriological cultures Tsokos and Püschel recommend spleen and heart blood and claim that results from lung culture are often unreliable due to frequently false positive results.[58] They also suggest that collection of specimens from at least two different sampling sites should be the standard procedure in cases where an underlying infection is presumed. Either plain swabs or swabs immersed in a transport medium can be employed for sampling a wide variety of sites at autopsy. Alternatively, tissue samples may be collected in sterile containers and this is the usual method for virological culture of lung and brain, for example. Blood cultures may be desired, and it is best to take blood with a sterile needle and syringe from a large vessel, such as the femoral vein, before starting the autopsy with its attendant inevitably widespread contamination with putrefactive organisms. Alternatively, blood can be taken from a freshly opened heart chamber using sterile instruments. If an infective endocarditis is suspected, it is best to open the heart later with a sterile scalpel and excise the mitral or aortic valve cusps or vegetations for direct culture.

According to a review of published articles on post-mortem bacteriology by Morris *et al.*, there are, in theory, four mechanisms through which bacteria can appear in post-mortem cultures: 1) invasion during life (genuine positive); 2) agonal spread i.e. bacterial invasion during the dying process or during artificial maintenance of circulation and respiration at resuscitation; 3) post-mortem translocation due to migration from the mucosal surface into the blood and body tissues and 4) through contamination where bacteria are introduced into the blood, CSF or tissues during sampling.[59] They conclude that the main post-mortem artefact is contamination, which can be considerably reduced by careful technique; agonal spread is less common than is often assumed and post-mortem translocation is not a problem if the body is appropriately stored. They further consider that a pure growth of a pathogen in blood or CSF should be regarded as a possible contributing factor to death at all ages.

It requires the expertise of an experienced microbiologist to advise on what is significant in the subsequent growth in the laboratory.

Toxicology

This has already been mentioned and is further discussed in the later chapters of this book but, as far as the collection of specimens is concerned, it may be repeated here that sampling is extremely important

REQUEST FOR TOXICOLOGICAL ANALYSIS

Name ______________________ Age ________

Post Mortem No ____________ Date of P.M. ____________

Date of Death ____________ Pathologist ____________

SPECIMENS SUBMITTED: ____ Blood ____ Urine ____ Liver ____

Stomach contents ____ Kidney ____

Intestines ____ Brain ____

OTHER SPECIMENS ____________

Any infective conditions suspected ____________

ANALYSIS REQUIRED

BACKGROUND INFORMATION:

Figure 1.22 Sample request form for toxicological analysis.

if reliable analytical results are expected. Blood, urine, stomach contents, organs (especially liver), intestinal contents, CSF, bile and ocular fluid may be required.

The containers in which specimens are collected must be chemically clean to a very high standard. They are often supplied by the laboratory that will carry out the analyses.

The pathologist should submit a form with the samples indicating the analyses required, the personal details of the deceased person, a brief history with details of suspected toxic substances and a statement as to whether the subject was known to suffer from any infective condition, including hepatitis or HIV infection (Fig. 1.22).

Histology

As long ago as 1893, Virchow pointed out in his book about dissection technique, with particular relevance to medico-legal practice, that certain pathological changes cannot be recognized by the naked eye, but only with the help of a microscope or a magnifying glass.[60]

It is advisable, whenever possible, to carry out a histological examination on a range of tissues in all autopsies and inevitably in all criminal or litigious cases, to confirm or to exclude the presence of a natural disease. In other situations histology may be able to provide answers in questions concerning the timing, vitality and causes of injuries or identification of the nature of aspirated or ingested material found in the airways or gut. The need to confirm the human origin of isolated tissue fragments may arise, e.g. in mass disasters, although molecular biological methods are necessary to establish the personal identity.

The Council of Europe recommendation on the harmonization of medico-legal autopsy recommend that histology be taken from every autopsy.[15] Similarly, the Royal College of Pathologists (United Kingdom) Guidelines on autopsy practice, September 2002, recommends as best practice the sampling of all major organs for histology in all autopsies.[14]

The Code of practice and performance standards for forensic pathologists by the Home Office Policy Advisory Board for Forensic Pathology and The Royal College of Pathologists,[61] and Code of Practice and Performance Standards for Forensic Pathologists dealing with Suspicious Deaths in Scotland by Scottish Government, Crown Office Procurator Fiscal Service

(COPFS) and The Royal College of Pathologists, recommend that:

> "A histological examination should be made, by the pathologists themselves, of the major organs (assuming that they are not heavily decomposed) in all suspicious deaths. Histology is of value in confirming, evaluating and sometimes revising the course of natural disease processes that may have contributed to the cause of death. Other samples should be taken for histological examination depending on the circumstances of the case, e.g. for the purposes of aging injuries. The reasons behind any decision not to undertake a histological examination must be adequately recorded, in order that the pathologist may be in a position to defend this decision if required.".[62]

This advice should be followed wherever possible, even though in some medico-legal autopsies, the cost of such techniques may provide difficulty if the coroner or other commissioning authority declines to fund the procedure. It is customary to retain samples of brain, heart, lung, liver, kidney, pancreas, spleen, thyroid, adrenal and muscle as a minimum. Even in decomposed bodies histology may sometimes reveal disease processes that without histology would remain undetected. The author (PS) once autopsied a hospital death, where a patient had been taken to the hospital because of back pain and a fall on the stairs, after which he had developed weakness of both legs, progressive paraparesis and associated sensory deficits. The patient died before diagnosis was made and the hospital pathologist refused to perform the autopsy as the cause of death was obscure. Due to further bureaucratic delays, the body was already decomposed when the medico-legal autopsy took place. As the autopsy was completely negative but the clinical symptoms had concentrated in the back, the spinal cord was removed along with other organs for histology. The results of all ancillary investigations, including toxicology, were negative, except for the histology of the spinal cord, that showed an abundant infiltration with inflammatory cells that, in spite of the advanced decomposition, were recognizable as granulocytes suggesting myelitis.

Where there are indications to examine other parts of the body, these are retained in addition to the routine tissues. One should always use sharp instruments for cutting to minimize mechanical damage to the tissues to avoid artifactual changes that may hamper the interpretation of the findings. Sites, where the samples have been taken from, have to be recorded and numbered in the autopsy protocol to enable topographical correlation and comparison with macroscopic findings and possible later review and quality assurance measures. The tissues are either sampled by taking relatively large pieces at autopsy (which are soon thereafter trimmed down to size) or by cutting blocks of a standard size (such as 20 × 12 × 3 mm) at the time of autopsy. The choice of appropriate histological methods is most important for reliable results. For routine histopathology most tissues are fixed using buffered formaldehyde to stop the autolytic processes and degradation by bacteria and to stabilize the proteins. The size and the thickness of the samples must be in compliance with the choice of the fixation and staining methods. The tissue is placed in a large volume of buffered formol–saline and allowed to fix for at least several days before processing. However, if special methods, such as immunohistochemistry, are used, shorter fixation time may be necessary, as too long fixation may destroy the antigenic properties of the tissue resulting in false negative results. The volume of fixative should be six times the total volume of tissue: it is all too common to see a mass of tissue squeezed into a small container, barely covered with formalin, half-fixed and even semi-dried.

Autopsy radiology and post-mortem imaging

An historical introduction

It is astonishing how quickly after the discovery of a new, unknown type of radiation, 'X-rays', in November 1895 by Wilhelm Conrad Roentgen (1845–1923), it was applied to forensic medicine.[63,64] The first record of radiology in medico-legal context dates back to 1895, when, only few weeks after the first radiograph of a human hand, X-rays were used in a clinical forensic case in Montreal, Canada. The experiment was done to locate a bullet in the leg of a gunshot victim. It also became the first X-ray plate to be admitted to a court as evidence in North America.[65,66]

Professor Arthur Schuster at Owens College, Manchester, UK, was one of the two physicists in Great Britain (along with Lord Kelvin), who had received from Roentgen the original monograph and photographs at the turn of the year 1895/96. In April 1896, Schuster was asked to travel to a remote mill town in the north of Lancashire, to locate bullets in the head of a dying woman. She had suffered four shots from a pistol fired at close range by her husband. As Schuster was unwell, he sent his assistants, C. H. Lees and A. Stanton to take the first plates. Schuster developed the plates himself and found three of the missiles in her cranium. A few days later he went himself to take another plate that eventually revealed the fourth bullet. As surgery was not possible and the victim died a week later this became the first recorded use of radiology in a homicide.[63,67,68]

In December 1896, an X-ray plate was admitted as evidence for the first time in the USA in Arapahoe County, Colorado. James Smith had been injured in a fall from a ladder while trimming trees, receiving an injury of the hip. The surgeon, who had been consulted some time after the injury, had made no attempt at immobilization of the thigh but had advised exercise of various kinds, as if treating a contusion, after which Smith had sued him for malpractice. An X-ray of the hip taken about 7 months after the law suit, revealed an impacted fracture of the left femur and was, after initial denial, eventually admitted by the court as evidence.[68]

Radiologic methods were gradually and increasingly applied to various fields of forensic medicine, e.g. in identification by comparison radiography matching of the frontal sinus pattern (see Fig. 3.24),[69–71] the skull (cephalometry)[72] and the dentition,[73–75] as well as in detecting vascular changes by post-mortem angiography.[76–79]

Relatively soon after the introduction of computed tomography (CT) in the early 1970s it was applied to clinical forensic medical purposes in patients with acute gunshot injuries to the head.[80] In the 1990s, the Institute of Forensic Medicine of the University of Bern started a joint research project with the Institutes of Diagnostic Radiology and Neuroradiology of the University of Bern using multislice CT (MSCT) and magnetic resonance imaging (MRI) post-mortem and comparing the results with autopsy findings. At present, only few centres in the world are routinely implementing post-mortem imaging, using mainly CT but also MRI as a screening method, prior to conventional autopsy (Fig. 1.23). One of the latest is the 'Postmortales Imaging Center' of the Zürich University Institute of Forensic Medicine, in Switzerland, inaugurated in November 2010 and comprising an MRI and CT facility in the immediate vicinity of the autopsy room.

The scientific literature in this field is rapidly accumulating and in the course of time will give us a more precise picture about the advantages and flaws of these methods. Because of the high costs of the equipment and the necessary personnel to run these, they will remain out of reach for most forensic departments for the time being.[81–112]

Figure 1.23 Radiography is essential before some autopsies. When available, advanced post-mortem imaging methods, such as CT but also MRI can be used as a screening method. Here a multiplanar reconstruction of humerus detected an abscess in its proximal part (arrow), which was confirmed to contain pus at autopsy. (Reproduced by kind permission of Professor C. Jackowski.)

The details of radiological findings are discussed in each appropriate chapter, particularly in relation to child abuse, gunshot wounds, identification and dentistry.

The quality of radiographic assistance available will vary widely from none to the most sophisticated techniques. The main difference is usually whether the autopsy is carried out in the mortuary of a well-equipped hospital where there is radiographic apparatus, radiographers to use it and radiologists to read the films – or whether the autopsy is performed in some remote public mortuary or in makeshift premises far from clinical facilities.

In many developing countries, radiography may be scarce for living patients let alone corpses, and the same standard of assistance for the pathologist cannot be expected. In larger, more affluent countries, remoteness may be the problem; here mobile equipment is available and sometimes used by forensic pathologists. There are small, portable X-ray kits that can be carried in two suitcases, and can function from an ordinary domestic power supply or from a portable petrol generator. In many instances a mortuary will have a small portable machine, sometimes one discarded from clinical use. This can be wheeled into position when needed, and films and technical assistance obtained from the nearest hospital, which is often adjacent.

For isolated organs and tissues, cabinet-type radiographic equipment is available, which can be used without the assistance of trained radiographers.

Where there is a large forensic institute, then full radiological facilities with the staff and equipment to operate and process plates will be available at all times. Where research projects involving radiology, such as post-mortem coronary angiography, are being carried out, there will usually also be ample facilities for routine use.

The stage at which radiology is employed in an autopsy will vary according to the individual circumstances, but is likely to be after the external examination is complete, but before dissection begins. Straight radiographs for bony injury are not often required, as the skeleton can be inspected directly by dissection in major trauma. The exception is child abuse, where, as fully described in Chapter 22, a full skeletal survey is needed before autopsy. Indeed, many forensic and paediatric pathologists would consider radiology essential in all infants who did not die of some obvious disease.

Suspected air embolism, pneumothorax, barotrauma, gunshot and explosive deaths should have radiological examination before the autopsy, and when a traumatic subarachnoid haemorrhage is suspected, vertebral artery angiography might be necessary, as described in Chapter 5.

Mutilated remains, especially those from mass disasters, may need to be X-rayed, as may victims die from fires where the external damage makes dissection difficult. Where bombs or explosive devices are involved, it is essential to have radiographs to detect any parts of the mechanism that are embedded in the tissues.

Though the radiographs are usually taken before the autopsy begins, some lesions may be better demonstrated on isolated organs or structures. In child abuse, the callus of old fractures of posterior ribs may be better visualized on X-ray if the chest cage is dissected out, and radiographs taken without the soft tissues and the obscuring structures of sternum and anterior ribs. Similarly, a block of upper cervical spine may better reveal fractures of transverse processes carrying the vertebral artery, or a larynx may show fractures of the hyoid or thyroid cornuae more clearly when they are X-rayed outside the body.

Forensic photography

Many forensic pathologists take their own photographs of both scenes of death and of autopsy appearances. Others rely on professional photographers such as the police and hospital medical photographers. The standard of expertise amongst some doctor photographers is excellent, and their pictures grace many lectures and textbooks. It is to the more inexpert camera operators that these few general tips are offered.

Recent advances in electronics have totally revolutionized photography, and have wide application and potential for forensic and autopsy work. Digital cameras of varying grades of sophistication, resolution and cost, can now instantly store images on various data storage devices and the images can then be reviewed immediately on a camera or computer display or printed on an inkjet or colour laser printer. The advantage of instant prints is that a record of the scene of death can be obtained before the autopsy is carried out, and any findings checked back against the original surroundings. For example, if some linear mark is seen on the leg at autopsy, the pathologist can immediately refer to his digital prints to check whether that leg had been resting on some object. Again, where multiple injuries exist, their number, position and size can be checked when writing the autopsy report, without waiting for the police album to arrive. Correlation of wounds with blood splashes may also be useful.

These images can be processed in many ways to enlarge sections or correct colour balance, sent via computer networks to distant locations, or incorporated within textual material and reports. Alternatively, conventional photographs and slides can be scanned within minutes, the optical image being digitized into electronic storage for similar processing.

Various storage media, such as various optical discs (CD, DVD, BD), flash drives, hard drives and solid-state drives offer huge storage and retrieval capacities for record-keeping and educational display purposes. In addition, single frames from video camera recordings can be captured as still pictures and electronically stored.

If conventional photography is preferred, the type of camera most favoured is the 35 mm single-lens reflex, of which there is a vast range available, in all grades of sophistication and price. Some means of exact focusing is essential (either automatic or split-screen, for example) as picture sharpness is of prime importance.

The type of lens is a matter of personal choice, as some will prefer interchangeable lenses of various focal lengths. The standard 50 mm is most useful, but for scenes of crime or taking a full-length shot of a body in cramped conditions, a wide-angle lens of 28 or 30 mm is needed. A longer focal length of up to about 80 mm can be useful for close-up pictures of small lesions, but telephoto lenses of 100–200 mm are not required, though extension tubes, some with lenses, can be obtained for macrophotography.

Many pathologists, including the authors, prefer to combine lenses into a single variable-focus 'zoom' lens of 28–80 mm range. This saves time spent in changing lenses, and the image resolution of good-quality equipment is virtually indistinguishable from fixed focal length lenses.

Illumination is usually by electronic flash now often an integral part of the camera body, and the use of automatic thyristor control means that no complicated calculations about range are needed. For very close-range work, a flash attached to the camera may be unsatisfactory, so an extension cable is a useful and cheap accessory to keep the flashgun at a distance. Alternatively, the flash can be 'bounced' off the ceiling in the autopsy room or a 'ring-flash' around the lens used to avoid camera shadow.

Some will prefer tungsten light rather than flash, though this is more cumbersome unless a fixed station is installed in the autopsy room for taking photographs of organs. It is impracticable to use floodlights at the autopsy table or at a scene.

The type of film depends on the nature of the illumination. Speeds of 100 or 200 ASA are more than adequate for most flash work, though 400 ASA is now frequently used. Some keen medical photographers carry a separate camera body loaded with high-speed 1000 ASA film for special circumstances.

Ultraviolet (UV) and infrared sensitive film has been used to demonstrate surface lesions that are not visible to the human eye. It has been claimed that occult bruising can be revealed by UV photography, such as in child abuse, but care must be taken and experience gained to eliminate artefactual false positives. Alternative light source illumination has been applied to bite mark photography.[113] David and Sobel reported a rape case, where the bite mark had at the time of the crime been photographed without a reference scale, but 5 months later the authors were able to 'recapture' the bite mark pattern with a reference scale by means of reflective ultraviolet photography.[113,114]

In relation to the actual photography, a marked improvement in the pictorial quality can be achieved with a little care in composition. At scenes of death the viewpoint is often limited and the surroundings have to be photographed as they exist, without modification. The camera position can, however, usually be chosen to cut out as much extraneous background as possible. In the autopsy room, considerable improvement can be made by using the optimum viewpoint and by modifying the background. Many photographs are spoiled by having irrelevant and distracting objects in the background such as observers, buckets, boots and the other extraneous paraphernalia of the autopsy room. The picture frame should be filled as completely as possible with the object under display. A close shot should be taken to limit the irrelevant margins though, where necessary, anatomical landmarks should be included to orientate the viewer. The camera should be at right angles to the lesion being photographed, whenever possible. Tangential shots may foreshorten the required feature and, where size needs to be displayed, may distort both shape and length because of the foreshortening. A ruler or special white adhesive tape with centimetre markings should be placed very near the lesion or wound to provide a size reference (Figs 1.10, 1.11).

Where a feature is obscured or insignificant, it may be pointed out by a probe or finger held in the appropriate position. Where part of the picture area consists of the metal or porcelain autopsy table or dissection bench, allowance should be made in exposure, as these very reflective areas may give a false reading in the light meter of the camera and thyristor of the flashgun.

If a full length or half shot of a body is required, an untidy background may be avoided by turning a mobile or rotatable table so that a blank wall forms the backdrop. If this is not possible, assistants can hold up a sheet behind the table to screen the distant confusion.

When photographing viscera, the camera should be near enough for the frame to be almost completely filled by the required object. The shot should be vertical to the lesion and it is often necessary either to place the dissecting board on the floor, or for the photographer to stand on a stool or some elevation to gain the required height.

Where isolated organs are being photographed, they should be placed on a green or blue cloth, such as a discarded operating gown. White can be used, though it may affect the exposure meter if much is visible around the periphery. The organ should be placed on the cloth in one movement and not moved thereafter, otherwise a wet dark stain will obtrude on the green or blue background. The organ should not be oozing blood onto its surface or onto the background. It should be dabbed with a dry cloth or sponge just before the photograph is taken to remove shiny wet highlights.

Ideally a special stage for organs should be used, such as a glass-topped table with a coloured (usually green) background set sufficiently far below the glass to be out of focus. Tungsten lights can be used to advantage on such a fixed stage.

The autopsy report

Equally important as the autopsy itself is the report that the pathologist provides for whoever commissioned the examination. An autopsy is of little value if the findings and opinion of the forensic pathologist are not communicated in the most lucid and helpful way. The report is an integral part of the procedure and should receive as much attention as any physical procedure in the autopsy room. Unfortunately, some pathologists treat the process of making a report in a somewhat cavalier manner, which diminishes the expertise that they may otherwise possess.

The autopsy report is a permanent record of the findings and is especially vital for medico-legal purposes, when every word may be dissected in a court of law months or even years afterwards, and when all recollection of the examination has been driven from the mind of the pathologist by hundreds of subsequent autopsies. In a clinical autopsy in a hospital, the dissection may be demonstrated and discussed at the time with the interested physician. However, the report of a forensic autopsy becomes a legal document of possibly vital significance, and every effort must be made at the time to make it as comprehensive and useful as possible.

The form of the autopsy report

Reports fall into two main types described below, and local practice and indeed legislation may determine which is used, irrespective of the wishes of the pathologist. The choice is, however, often dictated by the nature of the case.

- A free-style 'essay', which usually adheres to a conventional sequence, but leaves the pathologist free to expand on various aspects according to his estimate of their importance. This type is usually used in criminal deaths and cases in which litigation is likely. It has the advantage that any part of the autopsy can be expanded without constraint; also the form of the report can be turned into a legal statement or a deposition for the court with little alteration.
- A printed proforma, in which the various sections of the examination and organ systems are already set out by title, leaving blank spaces for the insertion of the findings. The advantage includes the fact that this 'shopping list' acts as an *aide-mémoire* to those pathologists who do not conduct large numbers of autopsies – and also the non-medical recipient is more able to follow the set pattern of the report. One disadvantage is that the spacing prevents flexibility of description unless the proforma is large, when much of the space may be left blank. Also there is rarely enough space at the end of the form for an expansive discussion and opinion about the preceding factual findings. This type of form is commonly used for non-litigious autopsies – for example, the usual coroner's cases of sudden death and suicide.

Concentrating upon the more serious cases, the report, whatever the format, must contain certain information in some logical order. Consecutive numeration, computer codings and other administrative aspects are naturally conditioned by local practice, but the following matters must be catered for in all autopsy reports, though not necessarily in this sequence:

- Full personal details of the deceased subject, unless unidentified. This includes the name, gender, age, occupation and address.
- The place, date and time of the autopsy.
- The name, qualifications and status of the pathologist.
- Persons present at the examination.
- Usually, the authority commissioning the autopsy.
- A record of who identified the body.
- The name and address of the deceased subject's regular (or last) medical attendant.
- The date and time of death, where known.
- The history and circumstances of the death. The inclusion of this on the actual autopsy protocol may not be permitted in some jurisdictions as it is hearsay evidence, but unless expressly forbidden it should be included, as it remains a record for the pathologist's own files. It also justifies his eventual cause of death in those cases where the morphological findings are scanty or even absent, as his conclusions will

be strongly influenced by his pre-knowledge of the mode of death. When the autopsy report is converted to a statement or deposition for legal use, this history may be omitted by those legal authorities responsible for transcribing the document.

- External examination.
- Internal examination.
- A list of specimens and samples retained for further examination. Those handed to other agencies, such as the forensic science laboratory, should be formally identified by means of serial numbers and the name of the person to whom they were handed.
- The results of further examinations such as histology, microbiology, toxicology and clinical and/or forensic genetics. When the main report is issued soon after the autopsy, these will not yet be available and a supplementary report will be necessary.
- A summary of the lesions displayed by the autopsy (often coded for departmental computer retrieval).
- Discussion of the findings, if necessary in the light of the known history.
- An opinion as to the definite or most likely sequence of events leading to the death.
- A formal cause of death, in the format recommended by the World Health Organization, suitable for the completion of a death certificate.
- The signature of the pathologist.

The 'external examination' should record those details described earlier in the chapter, the major items being:

- The height, weight and apparent state of nutrition.
- The presence of natural disease such as oedema, abdominal swelling, cutaneous disease, senile changes, and so on.
- Identifying features such as skin colour, tattoos, scars, congenital or acquired deformities, dentures, eye colour and hair colour. When identity is an issue, naturally this section will be greatly expanded.
- The presence of rigor, hypostasis, decomposition and abnormal skin colouration. Body and ambient temperature should be recorded where appropriate, with calculations concerning the estimated range of times since death, though this aspect may well be deferred until the final 'Summary and Conclusions'.
- The condition of the eyes, including petechiae, arcus senilis, pupil size and the condition of iris and lens.
- Condition of mouth and lips, including injuries, teeth and presence of foreign material.
- Condition of external genitals and anus.
- Listing and description of all external injuries, recent and old.

The internal examination records all abnormalities, usually in a conventional sequence such as:

- Cardiovascular system: heart weight, any dilatation, ventricular preponderance, congenital defects, the pericardium, epicardium, endocardium, valves, coronary arteries, myocardium, aorta, other great vessels and peripheral vessels.
- Respiratory system: external nares, glottis, larynx, trachea, bronchi, pleural cavities, pleura, lungs (including weight) and pulmonary arteries.
- Gastrointestinal system: mouth, pharynx, oesophagus, peritoneal cavity, omentum, stomach, duodenum, small and large intestine, liver (weight), pancreas, gall bladder and rectum.
- Endocrine system: pituitary, thyroid, thymus and adrenals.
- Reticuloendothelial system: spleen (weight) and lymph nodes.
- Genitourinary system: kidneys (weight), ureters, bladder, prostate, uterus, ovaries and testes.
- Musculoskeletal system: skull, spine, remaining skeleton and musculature where necessary.
- Central nervous system: scalp, skull, meninges, cerebral vessels, brain (weight), middle ears, venous sinuses and spinal cord (when examined).

The timing of the report

As with the format, there are two schools of practice in this respect. One advocates the issue of as full a report as possible on the gross findings as soon as the autopsy is completed, usually within a day or two. Obviously this can only be a preliminary, provisional report, as it may have to be modified (sometimes radically) by the results of ancillary investigations that may take days or weeks to return. Where modern polymerase chain reaction (PCR)-based bacteriological and virological diagnostic methods are not available, virological cultures, for instance, may take up to several weeks before a growth can be reported.

In a large proportion of forensic cases, however, especially those due to violence, the gross findings are unlikely to be substantially amended by ancillary investigations, though the possibility must always be left open until all data have been gathered in.

The other philosophy will delay any report (except perhaps a provisional oral opinion) until everything is to hand, when a single final document is provided.

Whichever course is adopted, one aspect is vital to both. The descriptive facts must be recorded at or immediately after the completion of the autopsy. It is vital that no significant interval – certainly no more than few hours – be allowed between the physical performance of the examination and the setting down of the objective findings. The words 'setting down' are chosen carefully as the report may be handwritten or typed, or may be dictated to a secretary or into a tape recorder or other audio system. What is vital is that it is not consigned to the pathologists' memory for a few days, even reinforced by notes written on scraps of paper.

In Britain and many other jurisdictions, the court may demand to see any contemporaneous notes and even tapes from a tape recorder. Any diagrams, notes or rough drafts must be preserved for production on demand of the judge, coroner or advocates in court. Where the report is dictated (either to a secretary or into a tape recorder), then the first typed (or word-processed) draft constitutes the 'original report', along with any contemporaneous notes including body sketches.

The use of printed body sketches can be a very useful aid in the autopsy room. Many versions exist from the simple front and back views of the whole body used in clinical neurology to multiple sketches portraying every possible view of the body surface. Separate diagrams are available for the male and female perineum, and for the different body proportions of infants. Used on a clipboard these diagrams can be most useful, especially where there are multiple injuries, or large areas of burns or abrasions. Each lesion can be drawn in, with a measurement noted alongside each and distances from anatomical landmarks recorded. The data from the sketches can be transposed to written form at the end of the examination.

Discussion and conclusions in an autopsy report

Some pathologists, usually those not normally concerned with criminal and litigious cases, claim that an autopsy report should be a bare recitation of the physical findings, with no discussion or interpretation of the significance of those findings. In the authors' opinion, this is an abdication of the pathologist's responsibility because, especially in criminal deaths, it is these conclusions that are of most interest and use to the investigating officers, lawyers and courts.

After the detailed description of the external and internal appearances, a short resumé should be offered of the major positive findings and their relationship to the cause of death. In many cases this will be obvious, as in a gunshot wound of the head. Matters such as the probable type of weapon, the range, the direction and the likely rapidity of death, however, should also be discussed.

When the findings are less clear cut, or are multiple, then the alternatives should be discussed, giving a differential diagnosis of the cause of death and detailing the possible sequence of events. If it is possible, a ranking order of probability of the various alternatives can be offered. Time of death and the limitations of accuracy in this particular case should be set out when the issue is relevant to the investigation. What is really required is as full an interpretation as possible, without venturing into the undesirable fields of unwarranted speculation or 'Sherlock Holmes' style of overinterpretation, which was the bane of forensic pathology in former years and is still practised too much even today, to the detriment of the good reputation of the speciality.

Post-mortem artefacts

Forensic pathology can only be learned by experience but no account would be complete without drawing attention to common artefacts found at autopsy, which can mislead the pathologist with insufficient forensic experience and even lead to a miscarriage of justice.

Some of the 'classic' mistakes were described many years ago by Shapiro and Moritz, but each generation of pathologists discovers them anew – or what is worse, fails to discover them.[115,116] Most artefacts are described in the various chapters dealing with specific lesions, but a reminder of some of the most important is given here:

- The pancreas is one of the first organs to undergo autolysis, because of the proteolytic enzymes within it. The autolysed tissue is often haemorrhagic and can easily be mistaken for acute pancreatitis, though histology will rapidly resolve the problem.
- Patches of haemorrhage, sometimes quite large and confluent, can occur in the tissues behind the oesophagus in the neck. These lie on the anterior surface of the cervical vertebrae and are caused by distension and leakage from the venous plexuses that lie in this area. They were described well by Prinsloo and Gordon and are sometimes known by this name.[48] Their importance lies in confusion with deep neck bleeding in strangulation (and sometimes with spurious neck fractures), which is why the skull should be opened before the neck in any suspected strangulation or hanging, to release the pressure in the neck veins before handling the tissues.

- Autolytic rupture of the stomach can occur post-mortem in both child and adult, described by John Hunter in the eighteenth century.[117] This so-called 'gastromalacia' appears as a slimy brownish black disintegration of the fundus with release of the stomach contents into the peritoneal cavity. Sometimes, the left leaf of the diaphragm is also perforated through a ragged fenestration, with escape of gastric contents into the chest.
- Heat fractures of the bones, either skull plates or long bones, may be seen in victims of severe fires, but are not evidence of ante-mortem violence. Also in conflagrations, the 'heat haematoma' within the burned skull can resemble an extradural haemorrhage of ante-mortem origin. The site is often at the vertex or occiput; however, unlike the usual parietal haemorrhage, there is no fracture line crossing the middle meningeal artery, the usual cause of a true extradural bleed. The frothy brown appearance of the false clot, together with heating effects in the adjacent brain, should indicate the true diagnosis. Shrinkage of the dura due to heat may cause it to split, with herniation of the brain tissue into the extradural space. Severe burns of the body surface may lead to heat contractures of the limbs with tears over joints such as the elbow. These must not be confused with ante-mortem lacerations or incised wounds.
- The bloating, discolouration and blistering of a putrefying body must not be misinterpreted as disease on injury. Blisters are quite unlike those of burns and dark blackish areas of discolouration must be distinguished from bruising. The latter can be difficult and incision into the tissues to seek blood in the dermis is advised. Histological sections may help but, where a body is badly decomposed, special stains for blood traces in the histological sections may assist, such as alpha-glycophorin to detect red cell envelopes. However, often it is quite impossible to differentiate the discolouration of decomposition from true bruising.
- Blood or bloody fluid issuing from the mouth may be due to putrefaction, even if the body surface is not overtly decomposed. If the lungs and air passages are discoloured and filled with sanguineous liquid, then this must be taken to be cause of the purging from the mouth and nostrils.
- Dark red discolouration of the posterior part of the myocardium is usually due to post-mortem gravitational hypostasis, not early infarction. Similarly, segmental patches of dark red or purple discolouration of the intestine is hypostasis, not infarction. The latter tends to be a single continuous length, the serosa being dull and the gut wall friable.
- Large petechiae or ecchymoses, sometimes with raised blood blisters, are often seen in the dependent skin of persons who have died a congestive death or where the upper part of the body has been hanging down after death. The usual place where these are seen is over the front of the upper chest and across the back of the shoulders, though in dependent heads the face may be shot with haemorrhages.
- Resuscitation artefacts are of increasing importance to the forensic pathologist and are discussed later.

Exhumation

Exhumation is the retrieval of a previously buried body for post-mortem examination. This is usually followed by a first autopsy or a re-autopsy following new information. The term 'exhumation' is usually applied to the removal of a body buried in a legitimate fashion in a cemetery or graveyard ('inhumation'), rather than the recovery of an uncoffined, clandestinely buried victim of a suspicious death. The latter is really a true 'scene of crime' and the pathologist should treat it as such.

Exhumations are required for one of the following reasons:

- Where all or part of a graveyard has to be moved for some development of the ground. Often no special examination of each body is made unless there is some historical or anthropological interest.
- Where some civil legal matter needs to be investigated, such as personal injuries for insurance or civil litigation for negligence – usually after a road, industrial or other accident.
- Where new information or substantiated allegations arise to suggest that a death was due to criminal action, either from injury or poison.
- In ancient or historical circumstances to investigate either the individual or a series of individuals for academic interest. A number of such investigations have been carried out on medieval and later inhumations in England, to study disease patterns and nutritional states in old populations – though many of these have been from dry vaults, rather than earth burials.

The legal procedures authorizing an exhumation do not concern us here, as they vary greatly from country to country. In all jurisdictions, however, there must be strict safeguards to identify the grave and the

Figure 1.24 Exhumation; the final approach to the coffin. Sometimes a metal cassion has to be used to protect the gravesides from collapsing (not here). The grave must be identified by the cemetery superintendent.

coffin, so that no mistake can be made. The grave must be positively identified by the cemetery authorities by reference to plans and records: an official must personally point out the grave to be opened.

Traditionally, exhumations are carried out at dawn but, except to avoid spectators and publicity, there is no real need to stumble about in a dark cemetery before first light. A better plan is for the grave to be dug down to just above coffin level by a mechanical digger or workmen on the previous day so that, the following morning, the police, coroner, pathologist and others can arrive in time to see the final exposure of the coffin. The coffin nameplate must be cleaned and read to confirm the identity, and, if possible, the funeral director who carried out the original burial should be present to identify the coffin and the plate (Figs 1.24, 1.25).

If there is a suspicion of poisoning, samples of earth should have been taken from the surface of the grave, from other parts of the cemetery and from immediately above the coffin. When the coffin has been removed, further samples should be obtained from the sides and beneath the coffin, but these matters will usually be attended to by forensic scientists.

When the coffin is lifted to the graveside it is as well for the lid to be loosened a little by slackening the holding screws or prising the lid loose. This allows foul gases to escape into the open air, rather than in the mortuary. The coffin is then transported to the mortuary; if it is in a bad state of decay, it may have to be supported on a rigid base such as a trestle, or placed inside an extra large coffin or fibreglass shell. Excess earth and mud should be removed before transportation to avoid excessive fouling of the autopsy room (Fig. 1.26).

Figure 1.25 Exhumation; when the coffin is exposed it must be identified by the funeral director and the coffin plate checked. If death from poisoning is suspected, samples of earth from above, below and the sides of the coffin as well as from a distant part of the cemetery must be taken, together with a sample of any grave water.

Figure 1.26 Following exhumation, the body is transported to a mortuary for full autopsy. The former practice of autopsy in inadequate premises near the cemetery is no longer justified. Here the original rotted coffin is placed within a temporary coffin for transit.

Where criminal action is suspected or has been alleged, a full photographic record must be kept (usually by the police) of every stage from identification of the grave to the findings during the autopsy.

At the mortuary, the coffin lid should be completely removed and the contents again identified, if possible by the funeral director who originally buried the body. He can again confirm the coffin plate, but also identify the internal coffin fittings, such as fabrics and shroud. When the body has not been buried for too long, he may be able to identify the features of the corpse from personal knowledge.

Figure 1.27 When the coffin is first opened in the mortuary, the coffin fitting and fabrics should again be identified by the funeral director, as well as the body and its clothes, if they can be recollected. This infant has been buried for 3 years. The upper part of the coffin has leaked, allowing liquid mud to cover and substantially destroy the head.

Figure 1.28 Exhumation after 9 months due to suspicion of death due to iatrogenic causes.

If poisoning is suspected, samples of the shroud, coffin trimming and any loose material such as packing or fluid should be retained for analysis. The body is then removed, undressed and a full autopsy carried out, as far as the condition of the body allows. Putrefaction, adipocere and mummification complicate the examination – sometimes, all three may be present in the same body.

The pathologist is sometimes asked by the authorities or by lawyers whether a proposed exhumation is worth carrying out, because of doubts about the usefulness of the result. Certainly the balance between the potential advantages must be weighed against the cost, publicity and distress to relatives that might be caused. In general, however, it is surprising how much information may be gained even when the body has been buried for many months or even a few years (Figs 1.27–1.29). Much will depend on the actual environment of the grave: a gravel or sandy soil, especially in an elevated position, will allow a body to remain in a much better state of preservation than one in the waterlogged loam of a valley. The author (BK) has seen burials only 20 years old with empty coffins containing silt, but no soft tissue or even bones (due to a constantly rising and falling water table) in an area of acidic peat.

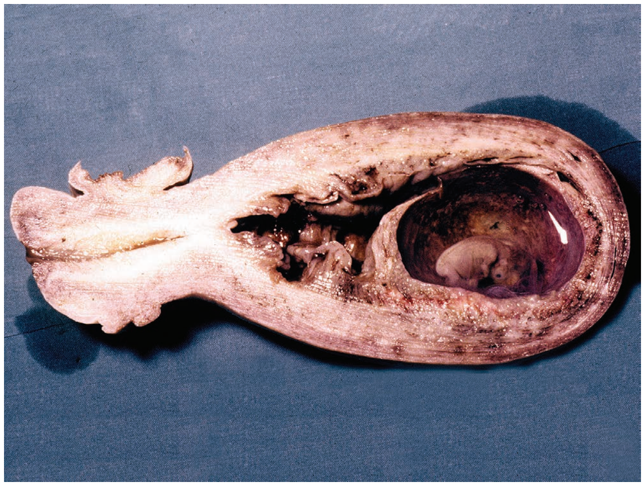

Figure 1.29 An early pregnancy found incidentally in a decomposed body, confirming the value of autopsy on even the most unpromising material.

Even negative information gained at exhumation, such as the absence of alleged or suspected fractures, may be of considerable legal value. Some poisons, especially heavy metals, may persist for many years in a buried body and be detectable at exhumation.[118] Even many organic chemicals may survive for a long time.[119–124] In all cases of suspected poisoning, it is vital that ample control samples are taken from the grave and its surroundings, to avoid the later accusation that any abnormal substances found were environmental artefacts or were unassociated with the corpse.

The autopsy on the putrefied corpse

In forensic work, decomposed bodies are commonplace, especially in warm climates. Though the value of an autopsy is progressively reduced as the state of putrefaction advances, no short cuts should be taken by the pathologist merely because of the unpleasant nature of the examination. However bad the condition of the corpse, every effort should be made to carry out the autopsy as near to the usual routine as possible. It is often surprising – as with an exhumation – how much information can be gained. The interior of the body is often far better preserved than the outward appearances would suggest, so a policy of defeatism that leads to a skimped examination should never be adopted.

Externally, putrefaction hides bruising to a variable degree, the greenish black colouration of the skin masking the usual features of contusion. Abrasions, lacerations, incised wounds and gunshot wounds may, however, survive severe degrees of decomposition. Loss of bloody fluid from the mouth and nostrils (the so-called 'purging') is often mistaken by the public, police and even some doctors as evidence of haemorrhage, but loss of serous, bloody or frothy fluid from any body orifice is common in the advanced stages of putrefaction (see Fig. 2.12).

Peeling and slippage of skin may hide some abrasions, though they may be visible when the desquamated epidermis is removed and the underlying skin examined. Marks around the neck from the tissues swelling with gas and becoming embedded in a collar have been mistaken for strangulation.

Where maggot or other insect infestation is present, some may be taken for expert entomological examination to help in assessing the post-mortem interval, as described in Chapter 2 (Figs 2.14–2.16, 2.27–2.29). As stated above, the external examination should be conducted as near as possible to the routine for a fresh body, and the back and perineum not neglected because of physical difficulties in handling the body.

Identity may be a problem when the facial features are too bloated for visual recognition. The usual procedures described in the next chapter may be employed where necessary. Fingerprints may be required by the police to assist in identity, but decomposition may seriously destroy the fingertips. These may become swollen and desquamate, or may shrivel and become leathery. Several methods of restoring the amputated tips have been described: some recommend a simple method of immersing the tips in 20 per cent acetic acid for 28–48 hours, when the shrivelling will swell to normal size. Others recommend immersion in glycerine.

Internally, much will depend on the state of decay. The abdominal and chest organs may be in a better state of preservation than the exterior. The subcutaneous tissues may be distended and crepitant with gas, as may be the swollen abdomen. Judicious penetration of the peritoneum with the tip of knife may be needed to release the pressure of gas. The technique of lighting the escaping methane with a burning newspaper may be spectacular and sometimes near explosive, but does little to reduce the smell and is not to be recommended.

Examination of the organs follows the usual pattern, modified according to state of putrefaction. The heart may be limp and discoloured, with haemolysis staining of the endocardium and vessels. The coronary arteries are often very well preserved, especially if atheromatous or calcified, or both. Ante-mortem thrombi may persist even after the muscle is semiglutinous. The larynx may be discoloured, but the hyoid and thyroid horns can be examined for fractures and may need to be X-rayed. It may be difficult to detect ante-mortem bleeding at the fracture sites. Fractures elsewhere in the skeleton naturally persist and may require radiography for their detection, as may foreign objects such as bullets.

The brain often decomposes early, and all too often is merely a pinkish-grey paste within the dura. Gross lesions like a large meningeal or intracranial haemorrhage may survive for examination, but the trauma of removing the calvarium and attached dura may seriously damage a semifluid brain.

In Belgium, a technique was developed in the University of Gent whereby the head of a decomposed body was removed from the body and deep frozen until solid. The head was then cut across in the coronal plane with a band-saw, leaving the brain in two halves within the cranium. These were then immersed in a large volume of formalin until fixed, when they could be removed in a relatively solid state for examination.

Internally, the detection of true subcutaneous bruising may be very difficult due to the discolouration of putrefaction. Histology is often highly unsatisfactory because of cellular lysis and degeneration; stains for haemoglobin may help in revealing focal collections of lysed blood, but are often diffusely positive even in control areas. Claims have been made for staining for glycophorin A to detect red cell envelopes, as opposed to diffuse haemolysis.[125]

Resuscitation artefacts at autopsy

In recent years, the advent of effective, but often aggressive and invasive, resuscitation procedures has made the task of the pathologist more difficult. At autopsy, injuries and abnormalities are now often found that could be due to terminal and even post-mortem resuscitatory measures. Where the pathologist is made aware of these, he can often exclude the damage being due to non-resuscitatory injury, though even when he is informed of the procedures they can still mask or mimic more sinister trauma. When he is not made aware – or such information cannot be made available – then the difficulties of interpretation are compounded.

There are now many publications describing resuscitation artefacts.[48,126–129] The following are the main categories of damage, for which the pathologist must always be alert:

- Bruising of the anterior chest wall, haemorrhage into the subcutaneous tissues and pectoral muscles, fractures of the sternum, fractures of the ribs, haemothorax, bruised lung, lacerated lung, pericardial haemorrhage, and even fractured dorsal spine, following energetic external cardiopulmonary resuscitation (CPR). Thoracic cage fractures are rare in children, however, because of the pliability of the ribs and costal cartilages, but it cannot be denied that they sometimes occur. The differentiation is naturally of vital interest where child abuse is being alleged.

  Internally all types of damage to the heart may occur, including ruptured atria and even ventricles, septal rupture and valve damage. The great vessels can suffer severe trauma, as described in the now extensive publications on resuscitation artefacts. Fat and bone marrow emboli in the pulmonary vessels have also been reported after cardiac massage.[128] Petechiae in the eyes and intraocular haemorrhages can occur after CPR, as well as after violent sneezing or coughing; they are well known to occur during whooping cough.
- Bruising of the face and neck, finger marks and nail marks on the face and neck, and damage to the lips and inner gums from mouth-to-mouth resuscitation, when the face and neck have been gripped by hands. Damage to lips, gums, teeth and pharynx can occur from the introduction of an artificial airway or endotracheal tube, especially in difficult, hurried emergency situations.

  Injuries to the larynx, even including fracture of the hyoid and thyroid cornuae, can occasionally occur from these procedures, which are difficult to distinguish from manual strangulation if the circumstances are obscure.
- Puncture marks for venepuncture may be confused with injection marks in drug dependence. The introduction of intravenous cannulae into veins in the neck may cause large haematomata and more diffuse bleeding into the tissues alongside the larynx. Similar bruising may occur around puncture sites in the arms and groin. Intracardiac injections leave marks on the chest wall and may lead to a slight haemopericardium. The effects of injected noradrenaline and electrical defibrillation on the histological appearance of the myocardium are well recorded, with contraction bands being the most obvious artefacts, which can be mistaken for pre-existing myocardial ischaemia.
- Damage to the mouth, palate, pharynx and larynx can occur from attempts to introduce a laryngoscope or airway. Even fracture of the mandible has been caused in this way. In infants, even digital clearance of the pharynx can cause mucosal damage. Damage to the pharyngeal mucosa may cause bleeding, which can seem sinister to police or relatives; this may be mixed with the fluid of pulmonary oedema to produce copious pink, bloody froth, seen in a number of cases, including SIDS.
- Electric defibrillator pads make marks on the chest, though these are usually easy to interpret, except where there is an unusual shape. Defibrillators and injected β-adrenergic catecholamines such as noradrenaline can, however, cause widespread histological damage to the myocardium, consisting of coagulation necrosis and contraction bands, which can be confused with infarction or electrocution. When both defibrillation and catecholamines have been used to resuscitate, the myocardial changes are even more marked.[126]
- During the Heimlich manoeuvre to clear an airway obstruction, rupture of the oesophagus, stomach and intestines have been reported.[130–132] The oesophagus can be perforated by an incorrectly inserted airway. In the abdomen, external cardiac massage may cause ruptured stomach, ruptured liver, and damage to spleen and pancreas.
- Gastric contents in the air passages may have reached there by spontaneous agonal regurgitation or by pumping the chest and upper abdomen during resuscitation attempts. This makes the finding of vomit in the larynx and trachea of even less significance as a cause of death, as discussed in Chapter 14.
- The administration of oxygen by mask or tube may cause damage, as can overenergetic mouth-to-mouth resuscitation. Ruptures of oesophagus and lung have occurred, and other types of barotrauma include ruptured stomach and intestine. Where a pre-existing gut lesion exists, the administered gas may escape into the abdomen. The diagnosis of a pre-existing pneumothorax may be impossible where forced ventilation has been administered.

- In the central nervous system, subarachnoid haemorrhage has been described after external cardiac massage, and from hyperextension of the neck to pass an airway or perform mouth-to-mouth resuscitation. The forced posture can tear the vertebral arteries, making another source of confusion for the forensic pathologist in this difficult area of potential trauma to the neck (Chapter 5).
- Myocardial and pulmonary bone marrow embolism has been reported following cardiac massage.[133]
- Retinal haemorrhages, classically a sign of raised intracranial pressure and of head injury, have also been described in whooping cough and after CPR.
- Miscellaneous artefacts of which every pathologist should be aware include: skin maceration from a body lying in urine, kerosene, and so on; post-mortem burns from adjacent radiant heat or hot-water bottles; and petechiae and larger haemorrhages in the face from postural hypostasis.

Mass disasters – the role of the pathologist

With the exception of the more dramatic murders, the activity which focuses most public attention on the work of forensic pathologists is the mass disaster. Unfortunately, such tragedies are becoming more common with the increase in terrorism, the expansion of travel facilities and the larger size of passenger aircraft. There has been a tragically frequent need for the expertise of mass disaster teams, following such events as the Zeebrugge and Estonian ferry capsizes, football tragedies like Ibrox Park, Heysel, Moscow and Hillsborough, crush tragedies at Mecca, and numerous massive aircraft crashes, such as Tenerife, Air India, Japan, Lockerbie, and the 9/11 terror attacks in the USA in 2001, recent major natural disasters such as the 2004 Indian Ocean earthquake and Tsunami as well as the 2010 Haiti earthquake, both of which with an estimated death toll of over 220,000.[134,135] Mass disaster management is a discipline in itself and only the briefest summary can be offered here, together with useful references at the end of the section (Figs 1.30–1.32).

Forward planning

Many pathologists will thankfully spend their entire careers without having to participate in a major mass disaster; a commonly accepted definition is the death of more than 12 victims in a single event. No one can predict when such a tragedy might occur, however, as typified by the 1988 Pan Am sabotage, when almost 300 bodies fell out of the sky on a quiet and unsuspecting Scottish village.[136–138] It is thus essential that every forensic institute, department and individual pathologist should make some forward provision for such an eventuality. In Britain, the Royal College of Pathologists have published a useful booklet on the role of the pathologist in these disasters.[139]

In most advanced countries each region now has a Mass Casualty Plan covering medical and hospital services, fire service and police. This is often very detailed, covering every aspect of transfusion, drugs, casualty transport, emergency surgery and anaesthesia. The plans are clinically orientated, but often completely ignore provision for the dead – or they have some cursory statement at the end such as ‘Mortuary accommodation will be provided’ with obviously no thought given to how several hundred corpses are to be accommodated and examined. Though clinical planning is, of course, vital – especially in rail disasters, multiple motorway crashes and urban bomb outrages – it has to be appreciated that, in many air crashes, there are few if any survivors, and that all the clinical planning may be redundant, leaving a massive and unprepared crisis in relation to the dead.

It is therefore essential that forensic pathologists should ensure that, in the area for which they are responsible, there is cooperative pre-planning that includes adequate provision for collection, accommodation, examination and disposal of large numbers of dead victims. Naturally the pathologist is usually in no position to do this alone, but he is often the person with the most foresight and professional knowledge to act as the stimulus and catalyst between the major agencies responsible for overall planning. These are usually the police and the local health administration. When a Mass Casualty Plan does exist, but has serious omissions in respect of dealing with the dead, or where no such plan exists, the forensic pathologist should energetically stimulate the responsible authorities into making a comprehensive plan. This entails a series of meetings to identify danger areas in the region (such as airports, motorways, railways and military installations), and to discuss potential buildings for temporary mortuaries, the provision of materials such as markers, plastic bags and labels, which may be needed in large quantities at a few hours’ notice. Communications between such groups as police, pathologists, mortuary and laboratory technicians, radiographers and dentists also need to be established in advance. The expertise of international funeral directors with experience in mass disaster fatalities is invaluable.

The objects of pathological investigation in mass disasters are:

- To retrieve and reconstruct bodies and fragmented bodies decently.
- To establish personal identity.
- To conduct autopsies on some or all of those bodies.
- To establish the cause of death in some or all, especially aircrew and drivers, and to assist in reconstructing the cause of the disaster.
- To obtain material for toxicological analysis (especially alcohol and carbon monoxide) where appropriate.
- To seek evidence of the cause of the disaster from autopsy examination, such as bomb or detonator fragments that may be embedded in the bodies.

Outline of necessities in mass disaster planning

Provision of pathologists and other staff

Depending upon the scale of the tragedy, it may be necessary to recruit other pathologists to assist. In large cities, there may be sufficient persons with expert forensic knowledge, but elsewhere, hospital pathologists may be able to assist; forensic pathologists from a distance may also volunteer. It has to be remembered that a really large disaster may need many days, weeks or even months of work, and therefore personnel may be unavailable for the whole period. In addition, whatever the degree of willingness and unselfish devotion offered by doctors and all other staff, the physical and especially psychological stresses of this harrowing work mean that strictly limited periods of work should be imposed. Apart from the deleterious effect upon the doctor, the standard of work declines dramatically with fatigue and therefore it is in the interests of the investigation – as well as of the pathologists – that sufficient staff be recruited. This may, however, be easier said than done. One person must be in overall charge of the investigation. Usually a senior police officer has the ultimate responsibility, but the medical aspects should be firmly under the control of a senior pathologist, though he must delegate extensively to avoid being swamped by less important tasks and thereby being rendered totally inefficient. Again, all these aspects are modified by the scale of the disaster. Proper facilities for meals, rest and washing must be established, and again forward planning is essential for these mundane, but vital, features. Forensic dental and radiological expertise will be run independently by their own specialists, but there must still be a nominal chief in the form of the senior pathologist who acts as overall co-ordinator and arbiter of medical matters.

When a disaster, almost always an aircraft crash, occurs in some remote place or abroad where there are no satisfactory forensic or pathological services, it is the usual practice for a team from the country of origin of the aircraft – or a volunteer team arranged at governmental level – to fly to the scene and provide expertise to the local authorities. In many advanced countries, especially Britain, the armed services have permanent aviation pathologists who deal with all service aircraft crashes anywhere in the world and who are often available to deal with, or attend as advisers, any civil air disaster.

Provision of mortuary facilities

Most hospital mortuaries and even larger public mortuaries have limited storage capacity for bodies, and even smaller provision for performing simultaneous autopsies. It must also be appreciated that the normal business of a mortuary has to continue even through a mass disaster, so the massive increase in work is an addition to, not a substitution for, the normal handling facilities. Where more than about 10 bodies are involved, most mortuaries cannot cope with these problems, especially when it has to be remembered that some of the corpses may have to be retained for considerably longer periods than usual if identification cannot be made rapidly. Thus external facilities will have to be provided in some temporary accommodation. When the disaster is a long distance from the regular mortuary, transport and other logistic considerations may make it imperative to store and examine the bodies nearer to the crash site. Again forward planning is essential to identify hangars, storehouses, empty factories, halls and other buildings near potential danger spots such as airports. Whenever possible, all bodies should be taken to one site, as the separation of identification sites is a recipe for inconvenience, delay and mistakes. It is sometimes necessary, especially in remote regions, to set up tented mortuaries, but this is a last resort as facilities cannot be laid on with the same degree of efficiency. Where the crash is totally remote, it is usual for the authorities or the armed services to bring out the dead by helicopter or other transport to an urban site. A prime example was the Mount Erebus crash in Antarctica, where the dead were flown back to New Zealand.

If a warehouse, or factory or building of similar size, can be used, certain minimum facilities are needed. Good electric lighting, portable lights for close inspection, and power points for radiographic equipment and electric instruments are required. Adequate piped water, and washing and toilet facilities are essential. If any of these is deficient, then portable generators and water tankers must be supplied by the armed services or the police. Telephone and, if possible, internet and fax facilities should be available for the input of identifying data.

In hot climates, or in the summer in temperate climates, body refrigeration is vital, not only for the decent preservation of the dead but for retention of tissues awaiting identification. If a disaster is too large to be handled in the usual mortuary, then some form of cooling is required. The renting of refrigerated trucks used for the transport of foodstuffs is the usual answer and, again, pre-planning is necessary to discover sources of such facilities. Sometimes portable air-conditioning units can be installed in part of the mortuary, if this is sufficient to cool the storage area to an acceptable level. In disasters where there are both living and dead victims, the mortuary should be sited away from the clinical facilities or screened in some way to avoid the distressing sight of bodies arriving being visible to survivors or their relatives, and the press.

The temporary mortuary should be large enough for the expected load, and the area to be used for examinations and autopsies should not be too congested. No one should be allowed in who does not have direct business there, no matter of what eminence or rank. Security of admission should be tight, this being the responsibility of the police. Flooring should be waterproof and capable of being hosed down. It can be protected against blood, mud and burned fragments by covering with polythene from large rolls. Tables for examination can be wooden trestles, covered with polythene. These should be in rows 1 metre apart, with 2 metres between rows.

Retrieval of bodies

This is the task of the police or armed services, but must be carried out in a manner approved by the forensic identifying team. It is essential that every body is first certified as dead by a doctor at the scene. Often, volunteer casualty surgeons may be the first medical persons at the scene, whose primary duty is to rescue living survivors and to confirm death in the remainder.

Each body or fragment should be flagged with a sequential and unrepeatable serial number and marked on a grid plan, being photographed *in situ* wherever possible. It is then bagged and taken with its numbered label to the mortuary. Different teams will have different methods of dealing with the logistics of handling data and, increasingly, this is being performed on either microcomputers or on terminals linked to a central computer. The police have responsibility for these aspects, as they collect and record the clothing and personal belongings that play such an important part in personal identification.

Figure 1.30 Temporary coffins used to transport victims of the m/s Estonia disaster from the archipelago to the autopsy facility. (Reproduced by kind permission of the National Bureau of Investigation [NBI], Finland.)

Either the same serial number is used from the recovery stage or a different 'pathology' number is begun in the mortuary, which must be matched up with the previous serial number. Everything that has come from that body, including clothing, wallets, rings, teeth and jewellery, must carry the same number.

The pathologist and lay assistants undress the clothed bodies, and dictate a description of what is found as accompanying artefacts. The clothes are stored in strong paper bags to avoid the fungal growth that inevitably appears on damp fabric kept in plastic bags.

Many items will have been found loose at the site, but they must all be tagged and an attempt made to relate them to a nearby body, though this is obviously fraught with error. The objects found on a body are recorded on an inventory form and a separate form (usually the Interpol document) used for the purely medical and anatopathological aspects. The latter data are acquired by meticulous and systematic external examination, followed by an internal autopsy if this is to be carried out.

Whether or not an autopsy is to be performed on some or all of the victims will depend upon facilities, availability of pathologists, the legal direction and the system prevailing in the particular country. The wishes of the legal authority, such as coroner, judge,

Figure 1.31 Particular problems are associated with mass disasters in warm climates as the time frame for visual identification is very short due to rapidly advancing decomposition. This scene is from the Indian Ocean Tsunami disaster in December 2004. (Reproduced by kind permission of the National Bureau of Investigation [NBI], Finland.)

Figure 1.32 The enormous magnitude of the Indian Ocean Tsunami disaster, huge number of victims, and lack of refrigerated storage facilities, led to an unorthodox attempt to cool down the bodies using large blocks of dry ice. (Reproduced by kind permission of the National Bureau of Investigation [NBI], Finland.)

medical examiner or police, will be the deciding factor in determining how many victims are subjected to autopsy. The pathologist should exert his influence where there is reluctance to sanction any autopsies, emphasizing the benefit to the crash investigators of autopsy data on key victims.

As mentioned, the aircrew or other persons in charge of a vehicle or train should always have a full examination and analysis of body fluids as part of the accident investigation. Full photography of the clothing and bodies should be taken, and then all physical features such as height, weight, gender, race, colouring, scars, tattoos and deformities must be recorded. The forensic dental examination is then carried out on those bodies where obvious identity cannot be established by non-medical or dental means.

Radiological examination will almost always be required to assist in identification from osteological features and dental aspects – and perhaps also to seek foreign bodies that may assist in accident reconstruction, such as metal fragments blown upwards into the thighs and buttock in a hold explosion in an aircraft bomb – or even parts of the bomb or detonator itself, more especially in land-based terrorist attacks.

Toxicology should be taken as extensively as possible, even from some of those bodies that are not to have an autopsy. The data acquired from this painstaking work is then forwarded to the police bureau who have been collecting personal data from the records and relatives of the victims, and efforts are made to match the two sets of data. This is increasingly being performed by computer, and many efforts have been made by international agencies such as Interpol to set up universally compatible systems so that data can be acquired and exchanged electronically via telephone systems and modems from any part of the world.

The obscure autopsy

Several surveys in various countries have shown that where a physician offers a cause of death without the benefit of autopsy findings, the error rate is of the order of 25–50 per cent, even in deaths in hospital. Thus the value of an autopsy in improving the value of death certificates is undoubted, but it still has to be conceded that the autopsy is by no means infallible in revealing the true cause of death. Estimates of the frequency with which autopsies fail to deliver an adequate or even any cause of death vary from pathologist to pathologist, as well as with definitions of what type of case a is included in such series. For example, SIDS could be considered to provide 'negative autopsies', in that by definition, no significant findings are discovered.

Even excluding SIDS, there is probably at least a 5 per cent 'failure rate' in autopsy series from large medical centres and forensic pathology departments. This rate will also vary according to the habits, personality and seniority of the pathologists involved. Contrary to what might be expected, a higher rate of negative conclusions will originate from older and more experienced pathologists than from juniors. The younger pathologist is often uneasy about failing to provide a cause of death, feeling that it reflects upon his ability, whereas the more grizzled doctor, enjoying the security of tenure and equality with – or even seniority over – his clinical and legal colleagues, is less inhibited in his admissions of ignorance when the cause of death remains obscure.

These 'obscure autopsies' are more common in the younger age group. Even apart from SIDS, many autopsies on infants, especially neonates, are less than satisfactory in terms of definite morphological lesions discoverable in the autopsy room or the laboratory. The deaths often have a biochemical or hypoxic basis and, though inferences can be made from the clinical history, even expert paediatric pathologists have to make do with minimal or even absent findings in a significant proportion of cases. In teenagers and young adults, up to the age of about 35 years, there is a higher proportion of negative autopsies than in the older group, which provides the vast majority of the autopsy workload. An example is the obscure syndrome seen in East Asia, where Thai construction workers in Singapore suddenly die with no demonstrable pathological cause. Similar cases occur in China, Japan and Hong Kong; known as 'Pokkuri death syndrome' (PDS) in Japan, 'Lai Tai' in Thailand, 'Bangungut' in the Philippines, 'Dream disease' in Hawaii and 'Sudden unexpected nocturnal death syndrome' among South Asian immigrants in the USA.[140]

This preponderance in the young may carry an inherent fallacy, even though there may be an absolute increase in the incidence of obscure fatal causes. The young adult does not have the almost universal overlay of degenerative cardiovascular disease that is seen in the older group. Thus it is probable that the same occult disease processes occur in that older group as in the young, but as the latter do not have other lesions that can be grasped (usually quite legitimately) as a valid cause of death, then nothing presents itself to the pathologist. For example, on one autopsy table might be the body of a male of 22 who dropped dead shortly after taking part in a football match. There may be no adverse medical history, the gross examination revealed nothing abnormal and subsequently full histology with special stains, full toxicological screening, and microbiological and virological studies, were unrewarding. No cause of death can be extracted from these negative findings and the case must be recorded as 'unascertained' – or, as Professor Alan Usher of Sheffield once pointed out, as 'unascertainable', if the pathologist is feeling particularly omnipotent!

On the next table in the autopsy room, however, may be a male of 60 who has been found dead with no available history. On examination he is found to have 60 per cent stenosis of the anterior descending branch of his left coronary artery, but no recent or old damage to the myocardium. Histology may well be performed, with no further information obtained. The cause of death is likely to be recorded as 'coronary artery disease' by most pathologists, yet he might well have died from the same obscure cause as the young male, but because he has just sufficient arterial degenerative disease to prove fatal, the latter is accepted as the most likely cause of death. This feeling of disillusion may be reinforced by the presence on the third autopsy table of another male of 60 who has been killed by a firearm, yet who has 80 per cent stenosis of all three coronary vessels, this obviously having played no part in the death.

Whatever the philosophical aspects of this problem, the practical difficulty remains of the pathologist's course of action when faced with negative findings in an autopsy.

At the end of the gross examination in the autopsy room, as the depressing realization increases that nothing significant has been found, further action will depend partly upon the facilities available to the pathologist, especially in relation to toxicological, biochemical, microbiological, virological and histological laboratory service.

Before proceeding further to review the dissection, attention must be paid to obtaining adequate samples for ancillary investigations. In many cases, especially where the history alerts the experienced pathologist that this might be a difficult case – and usually always in young people – samples of blood, urine and stomach contents will have been taken as routine during the removal and first dissection of the viscera.

If a blood sample has not already been taken, it should now be obtained, preferably from a peripheral vein such as the axillary or femoral to avoid contamination from the now empty trunk cavities. If urine was not retained from the bladder, a few drops may still be found in that opened organ by suction with a syringe. Stomach contents may well have been lost, but the liver can be retained for toxicological analysis. It might be useful to take vitreous humour if urine and stomach contents have been lost.

Some blood may be used for inoculation of blood culture bottles and swabs can still be taken for microbiological investigations. If a lung infection is possible, then either a few grams of lung tissue can be removed into a sterile jar, or swabs can be taken from peripheral bronchi or from the lung parenchyma itself. As the surface of all cut organs will have been contaminated during the first dissection, cuts should be made into the surface of the lung using a new sterile scalpel so that relatively fresh tissue is obtained for culture. At the same time, a cube of lung – or other organ if desired – should be taken into a sterile container for virus studies.

Before tissue for histology is taken, a full review of the more vital parts of the dissection should be reviewed. Even in younger victims the first area to be studied again is the coronary system, and in older obscure deaths it is essential to re-examine these vessels. Although the coronaries should have been transected at short intervals (not more than 3 mm apart) on the first examination, it is prudent to retrace each vessel carefully from the aortic origin distally, looking again at each cut segment and, where the interval appears too large, to make further intermediate cuts. In addition, it may be wise to join the segments longitudinally between cuts, in case a small isolated thrombus is lurking in the lumen. This should be done for common left trunk, anterior descending branch, left circumflex and right coronary artery.

This review of the coronary system sometimes pays dividends, especially in the middle-aged group that at first sight appears to have good coronary vessels. A tiny segment may be occluded or severely stenosed over a distance of only 2 or 3 mm, either by pure atheroma or by a subintimal haemorrhage, ruptured plaque or a localized thrombosis. If nothing is found, then after a quick review of the valves and great vessels, the myocardium can be sliced more extensively and a number of representative blocks taken for histology, to seek a myocarditis or some obscure cardiomyopathy.

The other organs should be examined again, the pulmonary arteries being scrutinized for pulmonary emboli in the smaller branches. This is rarely productive, but the author (BK) has on several occasions found multiple small emboli in more peripheral lung vessels, although whether these were a valid cause of death was debatable. The brain should be looked at once more, with special attention being paid to the basal arteries. These should be opened with coronary scissors and the dissection carried up into the middle cerebral arteries where they lie in the Sylvian fissures. It is also always worthwhile looking in the carotid arteries in the neck, though these should always be opened routinely at the first dissection from the aorta to a point just distal to the carotid sinuses; even the difficult area above this at the base of the skull has provided some surprises in the past. It is a place rarely examined, except by neuropathologists, but forensic pathologists should add it to their 'repertoire', as occasionally total thrombotic occlusion may be found, especially following some undisclosed neck injury.

When a complete review of the gross pathology has proved fruitless, then a full histological survey is required, especially of the myocardium. Special stains such as phosphotungstic acid-haematoxylin, dehydrogenase enzyme histochemistry (which requires unfixed, frozen sections), acridine-orange fluorescence stains and any other technique that the pathologist favours. Admittedly, where no cardiomegaly or coronary artery stenosis is present, the chances of finding an abnormality are slight, but an isolated myocarditis is an outside chance.

Toxicology may be difficult and expensive if there is no cause to suspect any particular drug or poison. A screen for unknown substances can be time consuming for the laboratory, which means a large expense to public funds. An alcohol estimation and a screen for acidic and basic substances, however, though not comprehensive, can at least exclude most common poisons. Microbiology and virology rarely point to a previously unsuspected fatal disease process unless the patient had clinical signs and symptoms before death.

When all the results are available, which may take several weeks, the case must be reviewed and an honest opinion offered as to whether any positive findings are sufficient to have caused death. In the experience of the authors, these ancillary investigations more often provide no help, than the times when they offer some assistance, but they must be carried out whenever possible in order to exclude such causes and to prevent allegations that the death was not investigated as fully as it should have been.

If at the end of the process no cause of death is apparent, then the appropriate investigating authority must be informed that no opinion can be offered in the present state of medical and scientific knowledge. It can be added, however, that the absence of injuries, evidence of poisoning, lethal infection or well-recognized natural disease is in itself significant negative evidence in that it confirms what the deceased did not die of, and the assumption is then that the balance of probabilities is that it was natural causes, rather than some unnatural external event.

There must be complete honesty on the part of the pathologist and a readiness to admit that the cause of death cannot be determined. The use of some meaningless euphemism such as 'heart failure' or 'cardiorespiratory arrest' is pointless and merely confuses the issue for non-medical persons such as police or magistrates. As mentioned above, there is a tendency on the part of some younger pathologists or histopathologists who rarely become involved in medico-legal cases to assume some unwarranted disease process or to attribute significance to insignificant findings. A **mode** of death is useless in lieu of a **cause** of death, so is the dangerous practice of using some agonal event such as 'inhalation of vomit' where there is no eyewitness confirmation of such an event taking place during life. It is also useless and positively dangerous to guess at some totally unprovable process, such as 'vagal inhibition', 'reflex cardiac arrest' or 'suffocation', just because these conditions – though valid in association with the right circumstances, as discussed elsewhere in this book (Chapters 14 and 15) – are thought to leave no traces and therefore a death with no traces must be due to such a cause. This is illogical thinking and has led to several miscarriages of justice in the past, as well as to far more family anguish.

As the pathologist increases in experience and maturity, he or she is more ready to concede that he cannot find a cause of death, and this is far more satisfactory. In forensic work, this is not 'abrogating responsibilities' but being objective, sensible and just. There is no point in producing a speculative cause of death if that cannot be substantiated in later court evidence or legal statements. It is, of course, quite justifiable and indeed, part of the pathologist's responsibilities, to discuss the range of possible causes with the authorities responsible for investigating the death, but to be dogmatic about a single cause where the grounds for such a decision are tenuous does not help anyone and can lead to unfortunate consequences.

The principle, 'whatever can possibly go wrong will', is probably well known to everyone from the daily life. It became generally known as Murphy's Law in 1949.[141]

When human errors accumulate in the spirit of Murphy's Law and interfere with the medico-legal cause of death investigation, it can have disastrous consequences as illustrated by a case experienced by the author (PS): a 46-year-old waitress was found dead in her bed in a normal sleeping position by her brother and her ex-husband and, for reasons unknown to us, the death was reported to the police as murder. The detectives who went to investigate the scene of crime did not find anything suspicious, but due to the sudden and unexpected nature of the death, a medico-legal autopsy was ordered. Murphy's law would have it that the post-mortem was first performed 1 week later. At the external examination, the classical signs of strangulation were quite obvious and the police were again notified and came to photograph the findings before the autopsy was begun. The following day the police photographer reported that there had been no film in the camera. A week later, the technician at the histology laboratory called having noticed that all the histology samples had been destroyed by decomposition. The substitute for the regular mortuary technician, who had been sick on the day of the post-mortem, had erroneously filled the containers with distilled water instead of formalin.

The boyfriend of the victim as well as her son, both of who had spent the previous evening together with her, were arrested but the boyfriend was soon released because he had an alibi. The son of the victim was kept the maximum time in detention but the police was not able to get any information from him.

Due to the multiple failures during the investigation, the unknown circumstances of death and a possible competitive cause of death found at the autopsy (evidence of heart disease and blood alcohol level of 1.7 U/ml) the case at first remained obscure.

One year later, another victim was found strangled and the perpetrator was caught immediately after the crime had been detected. When interrogated, he confessed having also strangled his mother the year before.[142] Although it is quite evident that the occurrence of such extreme cases can be minimized by painstaking methods of work, it is probable, that, like printer's error, they will obey Murphy's Law and remain imperishable.

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