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ESSENTIALS Forensic and legal medicine focuses on the interaction between law and medicine. All medical practitioners should have knowledge about the basics of forensic and legal medicine to call upon in the absence of specialists, hence it is important for any practitioner to be fully aware of laws, statutes, codes of practice, regulations, and pro- fessional standards within their own geographic region of practice. This chapter focuses on (1) diagnosis and forensic aspects of death, including death certification and the role (in the United Kingdom) of the coroner; (2) assessment of allegations of physical and sexual abuse, and of torture; (3) how to perform a postmortem (where pathology services may be limited); and (4) forensic use of medical biological tests, particularly genetic tests that can be helpful in determining the likely cause of otherwise unexplained deaths. Introduction Forensic and legal medicine embraces all aspects of clinical and pathological medicine. It focuses on the interaction between law and medicine. This chapter reviews four areas of relevance to the law and medicine, areas which are important in both day-to-day clin- ical practice and in the diagnosis of and determination of causes of death. The chapter is written from the perspective of those practising in the United Kingdom but broad principles apply across jurisdic- tions. Unless specified, the law in this chapter refers to the laws of England and Wales. It is important for any practitioner to be fully aware of laws, statutes, codes of practice, regulations, and profes- sional standards within their own geographic region of practice. Many of these matters may

be within the routine workload of fo- rensic physicians and forensic pathologists, but all medical practi- tioners should have knowledge about the basics of forensic and legal medicine to call upon in the absence of specialists. Diagnosis and forensic aspects of death The first breath is the beginning of death. (Thomas Fuller, English churchman and historian, 1608–1661) While in many cases death may be tantamount to being instantan- eous and its diagnosis unequivocal, a number of situations can arise in which the diagnosis of death can be challenging. Death can be a progressive process with a slow but inexorable cessation of various bodily functions. When, for instance, brain death has occurred while there is still evidence of cardiac output and perfusion of organs, a number of problems may arise. These tend to relate to the ques- tion of organ donation and transplantation. Unfortunately, there is no legal definition of death in the United Kingdom, nor any inter- national consensus on this. Gardiner's group have suggested that death equates with the irreversible loss of capacity for consciousness in conjunction with irreversible loss of capacity to breathe. The Academy of Medical Royal Colleges (AoMRC) provided guidance on the diagnosis and confirmation of death in 2008. This guidance was prompted by the difficulties that might occur in the diagnosis of death in certain hospital patients, such as those with severe traumatic brain injury or catastrophic aneurysmal subarach- noid haemorrhage who are being ventilated. In England and Wales, there is no requirement for a doctor to confirm death has occurred, to view the body after death, or indeed to report the facts of death, but in accordance with the Births and Deaths Registration Act 1953, a doctor who attended the deceased during their last illness is required to issue a medical certificate of the cause of death (MCCD) unless the case is referred to the coroner. Diagnosis of death In cases of decapitation or advanced decomposition of the body, the diagnosis of death is clearly not challenging, but there are numerous cases where there has been genuine difficulty in distinguishing deep coma from death. Modern resuscitative and life support techniques have highlighted the problems that are associated with basing the diagnosis of death solely upon cardio- respiratory criteria. The AoMRC has suggested that 'Death entails the irreversible loss of those essential characteristics which are necessary to the ex- istence of a living human person and, thus, the definition of death should be regarded as the irreversible loss of capacity for conscious- ness, combined with irreversible loss of the capacity to breathe'. This concept has been finessed and elaborated upon in the United States of America by a distinguished bioethics committee 27.1 Forensic and legal medicine Jason Payne-James, Paul Marks, Ralph Bouhaidar, and Steven B. Karch

Section 27 Forensic medicine 6542 and emphasis is placed on the total integrity and wholeness of the organism: Determining whether an organism remains a whole depends upon recognising the presence or cessation of the fundamental vital work of a living organism – the work of self-preservation, achieved through the organism's need-driven commerce with the surrounding world. When there is good reason to believe that an injury has irre- versibly destroyed an organism's ability to perform its fundamental vital work, then the conclusion that the organism as a whole has died is warranted. (President's Council on Bioethics (2008). Controversies in the Determination of Death) Therefore, the two core issues behind a biological criterion for death are the concomitant irreversible loss of the capacity for conscious- ness and for breathing. Diagnosis of death according to cardiovascular criteria In the recently deceased, formal clinical examination is required to ensure that the pumping action of the heart and breathing have both ceased. In some patients, this can be identified by, for in- stance, a combination of ECG and intra-arterial pressure moni- toring, but in those who are not being monitored, this should be done by auscultation over the chest for a timed period of at least a minute, and repeated again a few minutes later. Cardiorespiratory death can be diagnosed after an observed period of 5 min of asystole from which

an inference can be made that irreversible damage to the brainstem has occurred. The return of cardiac or respiratory activity during this period of 5 min would of course prompt a further period of 5 min of observation. Following such a documented period of asystole, the absence of pupillary reac- tion and motor response to corneal stimulation should be sought and recorded, and the time of death cited when these observations have been completed. If the cornea is still transparent and moist (usually until about 10 min after death if the eyelids were closed), and if in any doubt, it may be useful to examine the eye with an ophthalmoscope. The blood in the retinal veins usually breaks up into segments within 10 s of clinical death, a phenomenon referred to as ‘rail-roading’ or ‘cattle-trucking’. In all deaths, there is also blanching of all retinal vessels if the eyeball is pressed with a finger. The use of neurological criteria for the diagnosis of death In the United Kingdom, the code of practice for the diagnosis of brainstem death needs to invoke three essential parameters:

1. The presence of essential preconditions
2. The exclusion of reversible contributions to states of apnoeic coma
3. The formal demonstration of coma, apnoea, and the absence of any brainstem reflex activity To fulfil the essential preconditions, the patient in question should be deeply unconscious, apnoeic, and reliant on mechanical venti- lation. The patient must also have suffered some form of irrevers- ible brain damage such as intracranial haemorrhage, ischaemic stroke, trauma, or hypoxic brain injury. If the primary underlying diagnosis is uncertain, it mandates an extended period of clinical observation before a call is made about the irreversibility of the process resulting in persistent coma and apnoea. It is imperative that the cause of apnoeic coma is not the result of some form of metabolic disturbance, endocrinopathy, pharmacological agent, or hypothermia. Hilmo’s group in Tromsø, Norway, has emphasized that prolonged resuscitation is warranted in arrested hypothermic victims and this emphasizes the need to comply with appropriate exclusion criteria. It is important to emphasize that the effect of drugs which depress con- sciousness and respiration needs to be carefully taken into consider- ation. Particular problems may arise when sedative drugs have been administered as part of the intensive care management of the patient, where the identity of the pharmacological agent is unknown and the pharmacokinetics and pharmacodynamics of the drug are altered by problems such as multiorgan failure leading to impaired hepatic and renal elimination of the agent in question. Furthermore, drugs which have long half-lives can of course remain in the body for prolonged periods of time, particularly where renal and hepatic metabolism are also compromised. This problem is best managed pragmatically by carrying out a period of clinical observation equating to approxi- mately four times the half-life of the agent in question, or—if there is a specific antagonist for the drug concerned, such as flumazenil (a specific benzodiazepine receptor antagonist) or naloxone (a specific antagonist for opioids)—then these agents can be administered. It is also important to consider other potential reversible causes of apnoea such as high spinal cord injury and problems affecting the neuromuscular junction such as myasthenia gravis or Lambert– Eaton myasthenic syndrome. Muscle relaxant drugs also act at the neuromuscular junction and where they have been used therapeut- ically it would be prudent to use a nerve stimulator to ensure that their effect has worn off. Testing of brainstem reflexes with an apnoea test can be per- formed once the essential criteria and the exclusion of reversible conditions that can produce coma and apnoea have been excluded. The test has two parts, namely the examination of afferent and ef- ferent

components of brainstem reflexes mediated through cranial nerves, and an apnoea test, further details of which can be found in Chapter 17.11. The apnoea test is performed once it has been estab- lished that the brainstem reflexes are absent. These tests should be performed by appropriately experienced and qualified clinicians, and two sets of tests are required, but it is important to empha- size that the time of death is the time at which the first set of tests was completed and deemed negative. There may be certain circum- stances in which confirmatory testing by other means is required, for example, when there is difficulty distinguishing between cen- tral apnoea and loss of brainstem function and high cervical spinal cord injury, or where the effects of drugs cannot be excluded, or where it is impossible to perform standard brainstem reflex testing due to concomitant facial injuries. Confirmatory testing might in- clude EEG or the demonstration of absence of cerebral blood flow by catheter or CT angiography (Fig. 27.1.1). The diagnosis of brainstem death in children older than 2 months is identical to that used in adults, but in infants under 2 months of age and in preterm infants, diagnosis of brainstem death is prob- lematic and probably inappropriate although hypoxic ischaemic en- cephalopathy is usually the most frequent cause. Completing a medical certificate for the cause of death As Swift and West have highlighted, although death certifica- tion is a legal duty of a doctor implicit upon their registration, it continues to be poorly performed despite increased education at

 undergraduate level. It is important to set out within the MCCD a logical sequence of events taking into consideration the chain of causation leading to death and employing the World Health Organization format of 1(a), 1(b), 1(c), II. An example of this would be: 1(a) Acute hydrocephalus 1(b) Cerebellar metastasis 1(c) Squamous cell carcinoma of right lung II Chronic obstructive pulmonary disease, diabetes mellitus, ischaemic heart disease Thus, under 1(a) the proximate cause of death is set out and under 1(b) the disorder leading to the immediate cause of death is recorded, and if there is a further link to the condition set out in 1(b) it is recorded at 1(c). In II, other significant conditions which have contributed to death but are not related to the disease or condition causing it are set out. It should not be used to list every conceivable (and probably irrelevant) condition that has been visited on the deceased. The mode of dying should not be used as the cause of death. Putting terms such as ‘cardiac arrest’ or shock should be avoided. When filling out the MCCD it is important to avoid abbreviations. Thus, if ischaemic heart disease is entered on the certificate it should be written as such rather than ‘IDH’ or ‘IHD’. Similarly, if left ven- tricular failure is cited, it should be written in full and not as ‘LVF’. If diabetes is contributory to the cause of death it should be stated whether it was type 1 or type 2 diabetes. Old age can be used as the sole cause of death provided certain criteria and safeguards are followed. These would include the patient being 80 years of age or more, and that the certifying doctor has ob- served the progressive decline in health over the course of months or years, there are no identifiable diseases or injury that could be cited instead of old age, there are no suspicious circumstances or concerns which would require the death to be reported to the coroner, and that the relatives are satisfied by this explanation and cause of death. In April 2019 a new system of Medical Examiner (ME) was introduced in England & Wales. The Medical Examiner is a senior clinician with three main functions: 1) To ensure there is accurate medical certification of the cause of death; 2) To detect whether there were significant problems in the treatment or care of the de- ceased, and ensure they are reported and reviewed by clinical gov- ernance; 3) To increase transparency for the bereaved, listen to their concerns and explain the cause of death to

them. Additionally MEs are responsible for detecting problems in treatment and care and if they detect a significant problem they must refer the case either to the Coroner or the clinical governance system. Initially the role is non-statutory, but will become statutory in the future. It is intended that eventually all deaths are scrutinised by MEs, in hospital and in the community. The role of the coroner Deaths which should be reported to the coroner are those where: • the cause of death is unknown • the death cannot be certified as being due to natural causes • the deceased was not attended by the doctor during his last illness or was not seen within the last 14 days or viewed after death (it is possible this may be increased to 28 days—as in Northern Ireland) • the death was associated with suspicious circumstances or violence • the death may be linked with an accident (this is not time limited) • there is a possible issue of self-neglect or neglect by others • the death has occurred or the illness arisen during or shortly after detention in police or prison custody • the deceased was detained under any section of the Mental Health Act 1983 • the death was associated with an abortion • the death might have been contributed to by the actions of the deceased, for example, self-injury, overdose, or abuse of drugs or solvents (a) (b) Fig. 27.1.1 (a) Vertebral angiogram showing no intracranial circulation. Contrast is filling the extracranial branches of the vertebral artery. (b) Left carotid angiogram showing no intracranial flow of contrast but filling of the superficial temporal artery and other branches of the external carotid artery. The column of contrast within the internal carotid artery stops at the skull base.

Section 27 Forensic medicine 6544 • the death is due to an industrial disease or related in any way to the deceased’s employment • the death occurred during a surgical procedure or before full re- covery from the effects of an anaesthetic or was in any way associ- ated with the anaesthetic • the identity of the deceased is unknown. The coroner’s power to investigate is provided under section 1(2) Coroners and Justice Act 2009 (the Act) and provides that: If a body is lying within the coroner’s area; and i. the death was violent or unnatural, or ii. the cause of death is unknown, or iii. the death occurred while in custody or otherwise in state detention. NOTIFICATION TO THE REGISTRAR BY THE CORONER FORM A - NO POST MORTEM HELD PARTICULARS OF THE DECEASED CORONER'S CERTIFICATE that he is not under a duty to investigate the death under Section 1 of the Coroners and Justice Act 2009 Cottingham Registrar of Births and Deaths Entry No. Register No. To be completed by Registrar I (a) Disseminated renal cell carcinoma (b) (c) II (Where this notification relates to a still-born child, this should be stated) The circumstances connected with the death of the above person have been reported to me and I do not consider I am under a duty to investigate the death under Section I of the Coroners and Justice Act 2009 21st March 2016 Date Cause of Death Place of Death Date of Death Age (or Date of Birth) Sex Name and Surname To the Signed Name Appointment Jurisdiction Professor Paul MARKS Senior Coroner 59344-2016 Form 100A East Riding of Yorkshire and Kingston upon Hull SPECIMEN FORM - NOT TO BE USED Fig. 27.1.2 Examples of Forms 100A (a) and 100B (b) issued by a Coroner.

27.1 Forensic and legal medicine 6545 Then the coroner’s jurisdiction is engaged. The Act has introduced the new concept of the coroner’s investi- gation of a death with or without an inquest being heard. Under the Act, there are effectively three options: a. Preliminary inquiry b. Investigation without an inquest c. Investigation with an inquest It is possible to construct an algorithm based on this which outlines the action that will occur upon reporting a death to the coroner.

1. No substantive investigation takes place

2. Preliminary inquiry autopsy NOTIFICATION TO THE REGISTRAR BY THE CORONER FORM B - POST MORTEM held under section 14 of the Coroners and Justice Act 2009 Registrar of Births and Deaths Entry No. Register No. To be completed by Registrar that he does not consider it necessary to hold an inquest Cottingham PARTICULARS OF THE DECEASED SPECIMEN FORM - NOT TO BE USED I certify that a post-mortem examination of the body of the above person was made by the suitable practitioner named below, whose report disclosed that the cause of death was : Ia Acute hydrocephalus b Cerebellar metastasis c Squamous cell carcinoma left bronchus II and I am satisfied that it is not necessary to continue the investigation (Where this notification relates to a still-born child, this should be stated) CERTIFICATE FOR CREMATION/BURIAL ORDER (Details to be entered if certificate issued) Is a histological or bacteriological examination to be made? 21st March 2016 Professor Paul MARKS Senior Coroner East Riding of Yorkshire and Kingston upon Hull 59344 -2016 Jurisdiction Appointment Name Signed Date Address Issued on To Suitable Practitioner Cause of Death Place of Death Date of Death Age (or Date of Birth) Sex Name and Surname To the Form 100B No CORONER'S CERTIFICATE Fig. 27.1.2 Continued

Section 27 Forensic medicine 6546 3. Formal investigation autopsy 4. Formal investigation inquest In cases where preliminary inquiries cease, or following the estab- lishment of an unequivocal natural cause of death, the coroner will issue Form 100A or Form 100B (Fig. 27.1.2). Form 100A will be issued following a preliminary investigation in which neither a post- mortem examination nor an inquest are deemed necessary. It will set out the medical cause of death as set out by the deceased’s doctor. Form 100B will be issued following a postmortem examination that has established a natural cause of death and no inquest is required. In these circumstances, Form 100B replaces the MCCD. It follows the conclusion of preliminary inquiries or the conclusion of an in- vestigation. However, the coroner can lawfully take the view that an inquest may still be necessary if other circumstances give them rea- sonable suspicion that there is something unnatural about the death. Assessment of allegations of physical and sexual assault and of torture Introduction Assessing, documenting, and interpreting injuries, marks, or scars which have been sustained as a result of trauma or violence are key roles of any forensic physician or forensic pathologist. Crimes of violence—including interpersonal, as part of armed conflict, or ac- cident or terrorism—occur globally. Human rights abuses including cruel, inhuman, and degrading treatment and torture have become more widely recognized and documented. The purpose of assessment and documentation is, as far as pos- sible, to assist in establishing how a visible injury, mark, abnormality, or scar has been caused, which may often be at issue in courts or tribunals of law. In addition, the forensic physician’s role may be to assist in determining the relevance of an absence of visible injury. The skills of assessment and documentation should be within the remit of any doctor (and within the remit of appropriately trained other healthcare professionals). The interpretation of the causes of wounds, scars, and injuries is best undertaken by those with forensic expertise, as there may be many factors involved in such interpret- ation. That interpretation still requires best quality evidence, which may include a review of ambulance records, hospital records, opera- tive notes, and photographic images. In many cases, the initial examination and assessment may have been undertaken for purely therapeutic purposes and the forensic significance of the injuries may not become apparent until many weeks or months later. Scrutiny of the clinical notes at a later stage, possibly in court, may reveal serious deficiencies, which not only undermine the credibility of the individual practitioner but can also seriously prejudice the legal proceedings. The key to all

assessments is the taking of an appropriate history and undertaking an appropriate physical examination. The findings of the history and examination must be recorded contemporan- eously, clearly and unambiguously. If a case goes to court, all such documentation (e.g. contemporaneous medical notes—handwritten or computerized—including body charts and images) may be re- viewed critically by other doctors, legal advisors, and the courts. Consent for the examination and for subsequent production of a medical report must be sought from the individual being examined. It should also be borne in mind that false, vexatious, or frivolous ac- cusations of assault are made, and the examiner should be aware that false allegations and counter-allegations do occur, which may only become obvious at a later date. Assessment There are several factors to establish with regard to injuries, marks, and scars. Assaults may not be reported for days or weeks afterwards. In some cases, the only evidence may be fully healed and mature scars. There may be a number of injuries from different incidents at different times. Specific times should be sought for each. If more than one type of assault has occurred, clear records must be made of which injury was accounted for by which implement. Knowledge of the type of weapon used can be very important when assessing injury as particular implements can result in iden- tifiable injuries. The type of clothing worn should be noted. When examining any individual for injury all these features should at least be considered to see whether they may have relevance to the case (e.g. the amount of force for a knife to have penetrated the skin, or whether a bite is through clothing). These may be- come relevant as the examination progresses or as other accounts of any assault are given, or additional forensic evidence becomes available. The accounts given of injuries may be influenced by the effect of drugs and/or alcohol consumed by both complainant and suspect, and it is appropriate to assess the influence that these may have in each case. Different accounts may be (and very commonly are) given by different witnesses, but it is not the doctor’s role to determine which account is the correct one: they should use medical know- ledge applied to the evidence presented to assist the court in deter- mining the true account. In many cases, the medical interpretation is neutral. Documentation Documentation of injuries, marks, and scars can be in a var- iety of formats. Each case must include a written description of findings supplemented by annotated pro forma body diagrams. Increasingly, photographic images are used to supplement written descriptions and body diagrams. It is, however, crucial that images of adequate quality are taken, and that the time and date taken are recorded. The use of smartphones and tablets has dramatically in- creased the use of photography, but frequently the images are of such poor quality that they add little or nothing to the evidence. If photographic images are supplied, it is absolutely essential that the quality of the images adds to, rather than detracts from, the evidence. All images should be taken with rules and colour scales. There are now apps available which allow capture of all relevant documentation for evidential purposes by recording contempor- aneously a full history and examination, record audio or video im- ages, take still images and output these in the form of a draft report. These have the benefit of being accurately timed and geo-located (e.g. ForensiDoc®). Figure 27.1.3 illustrates examples of body diagrams and Fig. 27.1.4 shows an example of an appropriate image. Box 27.1.1 lists the characteristics of each injury that may be needed for appro- priate documentation. Re-examination of injuries or sites of injury 24 to 48 h after initial assessment is of use to see how injuries evolve and whether bruises have appeared or other sites of injury noted.

 Pre-and post-treatment examination and photography are often very useful. Classification of injury When recording findings, a consistent system of description ensures that the nature of each finding is described clearly, reproducibly, and

unambiguously in note form, utilizing accepted terms of clas- sification. As an example, the inappropriate use of the term lacer- ation to describe a cut can, if applied incorrectly, potentially alter the causation of a wound from one caused by a sharp instrument such as a knife, to a blunt impact such as an impact from a baseball bat, which may have a substantial effect on the judicial outcome. For medicolegal purposes, a standard nomenclature should be adopted when describing injuries, marks, and scars. Most visible injuries will fall into one of the groups shown in Box 27.1.2. Inflicted injury (whether deliberate or accidental) may be divided into two main types—blunt impact (or blunt force or blunt contact injury) and sharp implement injury. Blunt injury describes injury not caused by instruments or objects with cutting edges, and it can be caused in many ways, both direct (e.g. punch or kick) and indirect (e.g. by traction, torsion, and shear stresses). Injury is caused dy- namically, with possible movement of the body towards, away from, or with the impacting object. Examples of objects that can cause blunt impact injuries include fists, feet, baseball bats, police batons, and cars. A blunt force blow can cause a range of symptoms or signs and the resultant injuries are dependent on a number of factors including force, location, and impacting surface. The effects of blunt impact include no visible evidence of injury, tenderness (pain on pressure at the site of contact), pain at the site of contact(s), reddening, swelling, bruising, abrasions, cuts (lacerations), and broken bones. Each type of injury may be present alone or in combination. Bruises may mi- grate away from the point of contact by gravity after a period of time. Abrasions give a clear indication of the actual site of impact, bruises do not necessarily. Blunt impact injuries can be described (in terms of force applied) as being weak, weak/moderate, moderate, moderate/severe, or severe. Transport-related injuries may result in substantial blunt force injury, both direct and indirect, which can include avulsion of organs, occult bleeding, and rupture of hollow viscera. Absence of visible injury does not imply that no assault or injury has taken place. Sharp injuries are caused by any implement or object with cut- ting edges (e.g. knives, scissors, glass, and razor blades). Wheals and erythema (reddening) are also nonpermanent evidence of trauma caused by initial vasodilation and local release of vasoactive pep- tides following an injury such as a slap, scratch, or punch, which will leave no mark after a few hours. The classic features of the triple response of Lewis are present but no specific damage is done to any tissues, hence an initial reddening associated with pain with possible subsequent development of local swelling may be present initially, (a) (b) Fig. 27.1.3 Examples of body diagrams on which injuries, marks, and scars can be recorded.

 (c) Fig. 27.1.3 Continued

 but after a few hours will have completely resolved, unlike bruising which will still be present after 24 h or more. Reddening caused by vasodilation can be distinguished from bruising by applying finger pressure—bruises do not blanch on finger pressure. Bruises The terms contusion and ecchymosis have been used historically to differentiate between different types of injury but it is simpler and more appropriate to use the term bruise. Bruising is visible evidence of leakage of blood into soft tissues as a result of injury to blood vessels. Such discoloration changes in colour, shape, and location as the blood pigment is broken down and resorbed. Ecchymosis and contusion in the past were used variously to de- scribe different sizes of injury but do not enhance understanding of either causation or mechanism of injury and should no longer be used in the context of visible marks on the skin, although contusion is sometimes useful to simply describe blood leakage from damaged blood vessels in internal organs such as the brain. Haematoma should only be used to refer to a collection of blood forming a fluctuant mass under

the skin. Many bruises (unless patterned or in groups) are nonspecific in- juries and it is usually not possible to offer any detailed opinions on the agent responsible from the nature of the bruise alone. Some bruises, however, may have a pattern (a patterned bruise), or because of their shape, size, or location may have particular significance. Common types of patterning seen include intradermal (surface) and petechial (pinpoint) bruising, which can reproduce the pattern of the texture of clothing, the ridge pattern from the sole of a shoe or tyre, or the streaky linear purple bruising seen on the neck, wrists, or ankles caused by the application of a ligature. Beating with a rod-like imple- ment often leaves a patterned bruise consisting of an area of central pallor outlined by two narrow parallel bands of bruising, so-called tramline bruising. Figure 27.1.5 shows examples of various bruises. In children, nonaccidental injuries must be differentiated from bruises seen on toddlers and children associated with normal ac- tivities, play, or sports. Bruises may be seen on the neck in cases of manual strangulation and may be associated with other signs of as- phyxia, although fatal strangulation may occur with no external vis- ible evidence of compression. Abrasions An abrasion (or a graze) is a superficial injury involving only the outer layers of the skin and not penetrating the full thickness of the epidermis. Abrasions exude serum, which progressively hardens to form a scab, but they may also bleed as occasionally they are deep enough to breach the vascular papillae that corrugate the undersur- face of the epidermis in which case frank bleeding may be present at an early stage. More superficial abrasions which barely damage Fig. 27.1.4 Example of good quality image with rule and colour scale (this shows a healing, self-inflicted burn, where a heated signet ring had been applied to the skin). Box 27.1.1 Characteristics to be assessed for each injury (optional and dependent on history) • Location (anatomical—measure distance from landmarks) • Pain • Tenderness • Reduced mobility • Range of movement • Type (e.g. bruise, laceration, abrasion) • Size (use metric values) • Shape • Surface (e.g. ulcer, raised, macular, hypertrophied, keloid) • Colour • Orientation • Age estimation • Account of causation • Time and date of alleged causation Box 27.1.2 Classification of injury: types of injury and examples of implements or mode of causation Blunt force—not caused by instruments or objects with cutting edges • Blows • Traction • Poking • Squeezing • Gripping • Pinching • Gripping • Torsion • Suspension • Restraint Sharp implement • Knives • Bayonets • Machetes • Razors • Glass • Metal Burns • Cigarettes • Hot liquids • Flame Chemical Suspension Electrical • Power sources • Conducted energy devices — Cattle prods — Stun devices — Taser Miscellaneous

 the skin with little or no exudation of serum (and thus no or little scab formation) may be termed ‘brush’ or ‘scuff’ abrasions. Scratches are linear abrasions, typically caused by fingernails across the sur- face of the skin. Pointed but not-cutting objects may also cause linear abrasions and in order to differentiate them from fingernail scratches may be termed ‘point abrasions’. Abrasions are often due to movement of the skin surface over a rough surface or vice versa, hence they may have a linear appearance and close examination may show elevation of parts of the superficial epidermis to one end, indicating the direction of travel of the opposing surface. The patterning of abrasions is clearer than that of bruises be- cause abrasions may record a clear impression of the shape of the object causing them and, once inflicted, do not extend or gravitate: they indi- cate precisely the area of application of force. In manual strangulation, small, crescentic abrasions caused by the fingernails of the victim or assailant may be the only signs visible on the neck. A victim resisting a sexual or other attack may claw at an assailant and leave linear parallel abrasions on the assailant’s face. Some abrasions may be contaminated with foreign material such as dirt or glass, which may have important medicolegal significance. Such material should be carefully preserved for subsequent forensic analysis. In such

cases, consultation with a fo- rensic scientist can ensure the best means of evidence collection and preservation. Examples of abrasions are shown in Fig. 27.1.6. Lacerations Lacerations are caused by blunt force splitting the full thickness of the skin, most frequently when the skin and soft tissues are (a) (b) (c) Fig. 27.1.5 (a) A nonspecific (unpatterned bruise) to the left buttock caused by a fall backwards from 4m from a tree. (b) A patterned bruise caused by a metal dog chain impacting across the back. (c) A tramline bruise to the thigh caused by impact from a police baton. (a) (b) Fig. 27.1.6 (a) An abrasion to the right forearm from falling onto a road surface. (b) Multiple fingernail scratches to the face.

27.1 Forensic and legal medicine 6551 crushed between an impacting object and underlying bone. A typ- ical laceration is one caused by a boxer punching an opponent to the eye with a boxing glove with a laceration being caused by com- pression of skin between the glove and the orbital rim. As with abrasions, the site of injury is indicative of the site of impact. Lacerations have characteristic features but often mimic incised wounds (or vice versa), particularly where the skin is closely applied to underlying bone (e.g. the scalp). Lacerations are often irregular wounds caused by crushing and tearing of the skin. The margins may be bruised and macerated. Blood vessels, nerves, and delicate tissue bridges may be exposed in the depth of the wound, which might be soiled by grit, paint fragments, or glass. Incisions Incised wounds are caused by sharp cutting implements, often bladed weapons such as knives and razors, but anything with a cutting edge such as shards of glass, edges of tin cans, and sharp tools such as chisels may also cause clean-cut incised injuries. The margins tend to be clean, straight, unbruised, unabraded, and not inverted. The deeper tissues are all cut cleanly in the same plane. If the blade of the weapon is drawn across the skin while it is lax, it may cause a notched wound if the skin creases. Examples of incised wounds are shown in Fig. 27.1.7. Wounds which are longer than they are deep may be referred to as slash wounds. Stab and chop injuries Stab and chop injuries are caused by sharp or pointed implements and the wounds have a depth greater than their width or length. With such implements, a mixed pattern of sharp and blunt force in- jury may be seen, with some incised element, some laceration, and bruising and swelling and abrasion also present. This may not be obvious in the living victim. They are usually caused by knives but can also be inflicted with screwdrivers, pokers, and scissors, but if those implements are not sharp, then the term ‘penetrating wound’ is better applied. Although the external injury may not appear to be particularly serious, damage to vital structures such as the heart, liver, or major blood vessels can lead to considerable morbidity and death, usually from haemorrhage. Axes, machetes, Samurai swords, and other similar instruments, although capable of cutting, may also cause lacerations as the injury caused by the weight of the instru- ment (e.g. axe head) may also cause blunt injury. Examples of stab and chop injuries are shown in Fig. 27.1.8. (a) (b) Fig. 27.1.7 (a) An incised wound to the right upper arm. (b) An incised wound to the right face. (a) (b) Fig. 27.1.8 (a) A typical appearance of a single stab wound. (b) Multiple, unsutured, healed chop wounds from a machete.

Section 27 Forensic medicine 6552 Self-inflicted injury Self-inflicted injury refers to any attempt by an individual to hurt themselves and can include a variety of harms including cutting, overdose, or self-hanging. When assessing injuries it is important to understand which factors may indicate the possibility that an in- jury was caused by deliberate self-harm. Individuals injure them- selves for several reasons, including psychiatric illness, attempts to imply events took place that did not, or for motives of gain. Self- inflicted injuries have characteristics which are not diagnostic, but which together may give an indication of self-infliction. Table 27.1.1 lists features that may assist in the

recognition or suspicion that cuts or other injuries, such as scratches, are self-inflicted. All or some of these may be present, but their absence does not preclude self- infliction nor does their presence necessarily imply self-infliction. Examples of self-inflicted injuries are shown in Fig. 27.1.9. Bites A bite mark can be described as a mark caused by teeth alone, or by teeth in combination with other mouth parts. Biting is a dy- namic process and bite marks can be complex injuries. Certain features need to be considered when reviewing an injury said to be caused by a bite, which include addressing the following ques- tions: is it a biting injury; if so, is it human or is it animal? Other issues must also be considered: is the injury oval or round, does the injury have central sparing or discoloration from suction or nipping between teeth, is the mark made by two dental arches, are marks made by individual teeth visible, is detail of individual teeth visible, is there sufficient detail and evidence for comparisons to be made with biting edges of teeth, and does the appearance of the injury fit the alleged time frame? There have been many judicial concerns about the evidential weight of human bite marks (and by implication any bite mark). The American Board of Forensic Odontology and other groups have therefore raised the forensic threshold both for stating that injuries are bite marks, and for the levels of conclusion that can be stated following the comparison of a subject's dentition to an injury. The 'conclusion levels' for pos- sible human bite mark identification have been revised, and the following descriptions represent a revision to the previous bite mark conclusion levels prior to 2013: Human bite mark: human teeth created the pattern; other possibilities were considered and excluded. Criteria: the injury pattern displays features that reflect the gross, class, and individual characteristics of human teeth. Typically the upper and lower arch should be visible and identifiable. Suggestive: the pattern is suggestive of a human bite mark, but there is insufficient evidence to reach a definitive conclusion at this time. Criteria: general shape and size are present (gross features), arches are clear and visible, but distinctive features such as individual tooth marks are incomplete or distorted or a few marks resembling tooth marks are present Insufficient evidence: there are insufficient details to render an opinion as to the cause of the injury. Criteria: while some indication of gross fea- tures may be present, it is impossible to identify the arch shapes, or any other features supporting a causation by teeth. Not a human bite mark: human teeth did not create the injury. Criteria: clear evidence by morphology or size that the injury is unre- lated to human teeth. The revision of the bite mark guidelines was largely in response to the increasing concern both within the legal and forensic com- munities regarding the number of wrongful convictions associated Table 27.1.1 Features of possible self-injurious behaviour Characteristic Additional comments (1) On an area of the body that the individual can access themselves Sites less accessible, e.g. the middle of the back, are less likely (2) Superficial or minor injury Although more severe injury may be caused, particularly in those with psychiatric disorder (3) If there is more than one cut they are of similar appearance, style, and orientation Typically, self-inflicted cutting injuries are more superficial, numerous, and similar than those sustained in an assault from another, where the natural reaction of the injured person is to avoid repeated injury (4) If other types of injury (e.g. scratches, cigarette burns) are of similar appearance, style, and orientation As for (4)—more than one similar injury should raise an index of suspicion as to the possibility of self-infliction (5) Multiple similar injuries Raise a high index of suspicion as to the possibility of self-infliction (6) Parallel injuries As for (5) (7) Injuries grouped in a single anatomical region As for (5) (8) Injuries are grouped on the contralateral side to the patient's handedness A right-handed person will tend to harm themselves on the left hand side of the body (9) Tentative injuries Smaller or lesser injuries grouped with the main injuries suggest initial 'tentative' attempts at self-harm (10) Old healed scars in similar sites May indicate previous attempts at self-harm (11) Scars of different ages in similar sites May indicate repeated previous

attempts at self-harm (12) Slow-healing injuries Persistence of wounds that would otherwise have been expected to heal in the absence of any other factors (13) Psychiatric and related issues—such as eating disorders, drug and alcohol misuse There may be an increased incidence in association with these conditions (14) An intention to mislead and to mimic inflicted injury In cases of false allegations of assault

27.1 Forensic and legal medicine 6553 with bite mark evidence. Examples of bite injuries are shown in Fig. 27.1.10. Firearm and ballistic injuries The examination of fatal firearm and ballistic injuries is the realm of the forensic pathologist. Frequently, a hospital clinician or fo- rensic physician is asked to comment on the nature of the wound or wounds in nonfatal cases. As with all injuries within the forensic setting, it is essential that the initial appearances of the injuries be accurately described and the wounds photographed. This is par- ticularly important since subsequent surgical treatment may distort or completely obliterate the wound characteristics. Furthermore, any fragments, bullets, or pellets found within the wounds must be carefully removed and handed over to the appropriate authorities. Examples of some firearm wound are shown in Fig. 27.1.11. Defence injuries Certain type of injuries may be described as ‘defence’ injuries. These are injuries that are typically seen when an individual has tried to defend themselves against an attack and are the results of instinctive reactions to assault. When attacked with blunt objects, most individuals will attempt to protect their eyes, head, and neck by raising their arms, flexing their elbows, and covering their head and neck. As a result, the exposed surfaces of the arms become the impact point for blows. Thus the extensor surface of the forearms (the ulnar side), the lateral/posterior aspects of the upper arm, and the dorsum of the hands may receive blows. Similarly, the outer and posterior aspects of the lower limbs and back may suffer injuries as an individual curls into a ball, with flexion of spine, knees, and hips to protect the anterior part of the body. In sharp blade attacks, the natural reaction is to try and disarm the attacker, often by grabbing the knife blade. This results in cuts to the palm and ulnar aspect of the hand. On some occasions, the hands or arms may be raised to protect the body against the stabbing motion, resulting in stab wounds to the defence areas. Dating or ageing injuries Identifying a specific time or time frame to the infliction of an injury is one of the most frequently asked and possibly least frequently sat- isfactorily answered questions in forensic practice. Injuries inflicted (a) (b)
Fig. 27.1.10 (a) A typical human bite mark to the chest wall (the bite was through clothes). (b) A human bite to the chin with tissue loss (the appearance alone would not confirm this as a bite—it was witnessed). (a) (b) Fig. 27.1.9 (a) Multiple, superficial, self-inflicted scratches to the neck and upper chest. (b) A single, deep, self-inflicted wound to the right forearm by a left-handed individual.

Section 27 Forensic medicine 6554 shortly before examination (in both living and deceased) will show no clinical or pathological evidence of healing. The physiological healing process (whether of blunt or sharp force injury) depends on a number of variables including the site of injury, the force applied, the severity of tissue damage, infection, and previous treatment. Bruises resolve over a variable period ranging from days to weeks. The colours of a bruise can include (dependent on the assessment of the examining clinician) blue, mauve, purple, brown, green, and yellow. Many bruises exhibit multiple colours. One study which looked prospectively at bruise evolution by colour showed that a bruise with a yellow colour was more than 18 h old and that the colours red, blue, and purple/black could occur anytime within 1 h of bruising to reso- lution (up to 21 days in the study). The colour of bruises and the pro- gress and change of colour patterns cannot therefore be

used to time the injury, with the exception of a yellow bruise which may be con- sidered to be more than 18 h old. Additional factors (due to colour reproduction and colour perception) render even the 18-h evidence questionable. Studies show that estimation of bruise age from colour photographs is also imprecise and should not be relied upon as the colour values are not accurate. There is also great interobserver vari- ability in colour matching both in vivo and in photographic reproduc- tions. Recent work confirms that in children no evidential value for ageing of bruises should be attributed to colour. Abrasions sustained during life are usually red-brown in colour and exude serum and blood which harden to form a scab. This scab organizes over a few days, before detaching to leave a pink, often in- tact surface. This process may be modified by accidental knocking of scabs or picking or scratching at the scab site. In the absence of med- ical intervention, lacerations tend to heal with scarring, usually over a period of days or a week, whereas incisions, the edges of which are often apposed, heal within a few days although some may scar badly. Transient lesions Swelling, redness, and tenderness, although frequently caused by trauma, are not specific signs of injury. Although it is important to record whether these features are present, it must be borne in mind that there may also be nontraumatic causes for these lesions (e.g. eczema/dermatitis, impetigo). Red marks outlining an apparent in- jury (e.g. the imprint of a hand on the slapped face or buttock of a child) should be photographed immediately as such images may fade within an hour or so and leave no residual marks. Cruel, inhuman, and degrading treatment and torture The World Medical Association's Declaration of Tokyo in 1975 defined torture as 'the deliberate, systematic or wanton infliction of physical or mental suffering by one or more persons acting alone or on the orders of any authority, to force another person to yield information, to make a confession, or for any other reason'. The Declaration also laid down guidelines for doctors when faced with cases of suspected torture. The Istanbul Protocol (the Manual on the Effective Investigation and Documentation of Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment)—known commonly as the IP— provides standardized international guidelines for documentation of torture and its consequences. It became an official United Nations document in 1999. Box 27.1.3 identifies the chapter and annexe contents of the Istanbul Protocol. An updated version of the IP will be published sometime in 2019–2020. Anyone undertaking an as- sessment for the purposes of identifying abuse, ill treatment, or tor- ture should have read this document and understand its contents and implications, and preferably undergone specific training in its application. (a) (b) Fig. 27.1.11 (a) An upper left leg injury caused by simultaneous discharge of two 12-bore shotgun barrels. (b) Multiple skin penetrations to the right upper arm from lead pellets from a shotgun cartridge discharged from approximately 10 metres. Box 27.1.3 Chapter and annexe contents of
the Istanbul Protocol Chapters I Relevant International Legal Standards II Relevant Ethical Codes III Legal Investigation of Torture IV General Consideration for Interviews V Physical Evidence of Torture VI Psychological Evidence of Torture Annexes I Principles on the Effective Investigation and Documentation of Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment II Diagnostic tests III Anatomical drawings for the documentation of torture and ill-treatment IV Guidelines for the medical evaluation of torture and ill-treatment

 The most relevant parts of the Istanbul Protocol with reference to the documentation of the physical sequelae of such treatment are Chapter V and Annexe IV. Annexe IV provides guidelines for the contents of any report on the medical evaluation of torture and ill treatment. The headings for this evaluation are listed in Box 27.1.4. These guidelines will need to be adapted to the nature, circum- stances, and purpose of individual

assessments, and with regard to the context and facilities available at the time of assessment. For those tasked with the assessment of alleged victims of torture, the Istanbul Protocol also highlights principles common to all codes of healthcare ethics, including the need for informed consent, the need for confidentiality, and the duty to provide compassionate care. It also recognizes how these duties and principles are sometimes in apparent conflict with the demands or need of the healthcare profes- sionals' employer, which may include public bodies or state depart- ments. Chapter III of the Istanbul Protocol (the Legal Investigation of Torture) makes specific reference to the need for securing and obtaining physical evidence and medical evidence, and Chapter V (Physical Evidence of Torture) outlines the elements of establishing and identifying this evidence. The key elements for consideration are listed in Box 27.1.5. It is important when examining individuals to recognize that cruel, inhuman, or degrading treatment and torture may leave no visible injuries, marks, or scars. Each injury, scar, or mark docu- mented should be interpreted according to the Istanbul Protocol Interpretation and Classification of Lesions, as shown in Box 27.1.6. Box 27.1.7 shows the suggested examination sequence based on the Istanbul Protocol. Examples of specific injuries from torture techniques Ears are damaged by direct or indirect trauma. Insertion of objects into the ear or slapping one or both ears simultaneously (telefono) can disrupt the tympanic membrane. Otoscopic examination is es- sential, as is the need to test hearing and to observe for injury due to object insertion and the presence of petechiae. Balance and hearing may be affected by head trauma and such symptoms and signs may require further specialist evaluation at the earliest opportunity. All joints should be examined for range of movement and mo- bility. If individuals have been subject to substantial soft tissue in- jury, or severe burns, mobility may be limited due to contractures. Amputation of digits or limbs may have been undertaken. The na- ture of the amputations may indicate whether medical expertise was used in such procedures (Fig. 27.1.12). Forced positions such as hyperextension of the vertebral column in the hog tie/banana tie can produce compression fractures of the vertebrae, and electric shocks may produce compression or evulsion fractures due to violent, uncontrolled, muscle contractions. Box 27.1.4 Istanbul Protocol: guidelines for the medical evaluation of torture and ill treatment Possible considerations for evaluations: I Case information II Clinician's qualifications III Statement regarding veracity of testimony IV Background information V Allegations of torture and ill treatment VI Physical symptoms and disabilities VII Physical examination VIII Psychological history/examination IX Photographs X Diagnostic test results XI Consultations XII Interpretation of findings XIII Conclusions and recommendations XIV Statement of truthfulness XV Statement of restrictions on the medical evaluation/investigation (for subjects in custody) XVI Clinician's signature, date, place XVII Relevant annexes (e.g. clinician's CV, images, body diagrams, test results). Box 27.1.5 Istanbul Protocol: contents of Chapter V, Physical Evidence of Torture A Interview structure B Medical history • Acute symptoms • Chronic symptoms • Summary of interview C Physical examination • Skin • Face • Chest and abdomen • Musculoskeletal system • Genitourinary system • Central and peripheral nervous systems D Examination and evaluation following specific forms of torture • Beatings and other forms of blunt trauma: — Skin damage — Fractures — Head trauma — Chest and abdominal trauma • Beatings of the feet: — Closed compartment syndrome — Crushed heel and anterior footpads — Rigid and irregular scars — Rupture of the plantar aponeurosis and tendons — Plantar fasciitis • Suspension: — Cross suspension — Butchery suspension — Reverse butchery suspension — 'Palestinian' suspension — 'Parrot perch' suspension • Other positional torture • Electric shock torture • Dental torture • Asphyxiation • Sexual torture including rape: — Review of symptoms — Examination following a recent assault — Examination after the immediate phase — Follow-up — Genital examination

of women — Genital examination of men — Examination of the anal region E Specialized diagnostic tests

Section 27 Forensic medicine 6556 Neurological examination may identify motor and sensory neuropathies that reflect direct trauma (e.g. median nerve or common peroneal palsies), compression neuropathies from ligatures or hand- cuffs, or conditions such as vitamin deficiencies due to poor nutrition. Repeated, direct impact to the soles of the feet (falanga or falaka) with some form of rigid implement (e.g. stick, baton, or truncheon) can result in substantial and permanent deformity of the foot. Many different types of suspension are described. The most fre- quent types include cross or crucifix suspension where the arms are abducted and tied to a horizontal bar. 'Palestinian hanging' is the term used to describe when an individual is suspended with the hands and forearms tied together in extension behind the back and attached to a horizontal bar, or where the wrists are bound and attached to a ligature, again with the arms in extension behind the back. This type of suspension has great potential for major damage to the shoulder joint complex and creation of brachial plexus damage, and may well leave ligature marks (Fig. 27.1.13). Parrot Box 27.1.6 Interpretation and classification of lesion(s) This interpretation should be applied to every mark, injury, or scar identified. Not consistent: • Could not have been caused by the trauma described Consistent with: • The lesion could have been caused by the trauma describe but it is nonspecific and there are many other possible causes Highly consistent: • The lesion could have been caused by the trauma described, and there are few other possible causes Typical of: • This is an appearance that is usually found with this type of trauma Diagnostic of: • This appearance could not have been caused in any way other than that described Box 27.1.7 Istanbul Protocol: examination sequence (Not all may be required—the physical examination will be based on the history obtained.) • Skin • Face • Eyes • Ears • Nose • Jaw, oropharynx, and neck • Oral cavity and teeth • Chest and abdomen • Musculoskeletal system • Genitourinary system • Central and peripheral nervous systems Examination and evaluation following specific forms of torture: • Beatings and other forms of blunt trauma: — Skin damage — Fractures — Head trauma — Chest and abdominal trauma • Beatings to the feet • Suspension • Other positional trauma • Electric shock torture • Dental torture • Asphyxiation • Sexual torture including rape: — Examination following a recent assault — Genital examination of women — Genital examination of men — Examination of the anal region Fig. 27.1.12 Judicial amputation of thumb. Fig. 27.1.13 Shoulder joint disruption caused by prolonged suspension with the arms extended.

27.1 Forensic and legal medicine 6557 perch suspension describes suspension with the knees flexed over a pole and the hands or wrists tied to the ankles such that the pole passes anteriorly to the forearms. Neurovascular damage, with motor and sensory neuropathies are well recognized. Examination needs to determine the extent of structural disruption and the degree of neuropathy with an assessment of functional loss. There are many ways in which electricity can be applied to the body. Electric current is delivered via electrodes placed on the body, and substances such as gels or water may be used to ensure good contact and spread the delivery of electricity to avoid any physical traces. Certain devices (e.g. stun guns and other conducted energy devices) have fixed and nonvariable effects. Others may have means of varying the electrical current delivered. Electrodes, crocodile clips, or wires may be attached around the fingers, toes, or tongue; attached to the breast or nipples; attached to the genitals; or inserted in the vagina or anus to provide a return circuit. Pain and muscle contraction are the two main effects. Dependent on the type, dur- ation, site of application, current, and voltage, short- and long-term visible effects may include

burns and burn scarring. Asphyxiation or suffocation can cause a variety of injuries, symptoms, and outcomes ranging from no visible injury to death. Means of potential asphyxiation include placing a plastic bag or gas mask over the head, or covering the face in cloths and pouring water over them while the individual is restrained (waterboarding or dry submarino). This is in contrast to wet submarino where the individual's head is submersed in water. Assessment of sexual assault If the facilities and personnel are available, any sexual assault com- plaint should be dealt with in the same ways as any criminal in- vestigation for such, but in many places there may be no means of undertaking such assessments, and the skills and competences of those conducting forensic medical examinations of complainants and suspects of alleged sexual assault may be limited or absent. However, it is important that any individual asked to assess a po- tential sexual assault understands the basic principles of such an examination and recognizes when to seek additional or corrobora- tive assistance. A forensic medical and forensic scientific examination po- tentially assists the investigation of sexual crime in a variety of ways, including identifying perpetrators, corroborating accounts, excluding accounts, and confirming detail. The forensic medical assessment comprises a comprehensive examination, identifying injury, obtaining appropriate samples for forensic scientific assess- ment, and contemporaneous documentation (which may include photo-documentation). Interpretation of the significance of genital and nongenital in- juries will be crucial in the assessment of findings and is dependent on accurate documentation and nonambiguous use of terms to de- scribed findings. The forensic scientific input is directed at analysing scenes, recovering relevant evidence, and using a wide variety of analytic and technical methods (including fibre analysis, DNA ana- lysis, and toxicology) to assist the investigation. Forensic science can help determine the nature of sexual acts, the sex and possible iden- tity of the assailant, and potential links with other offences. From the medical examination, most samples taken are biological (e.g. swabs from the mouth, vulva, vagina, anus and/or penis; blood and urine for toxicology). Support to the complainant Medical care requires safety and privacy and must be arranged appropriately to address treatment of injuries, risk of pregnancy, and risk of sexually transmitted infection (including hepatitis and HIV). These are required in all circumstances, including for those in detention. Management should also include risk identification of self-harm and suicide, as well as safeguarding children and vulner- able adults. For nonacute and/or past sexual assault, consideration must be given to risks of conditions such as post-traumatic stress disorder. Pregnancy prevention may be required using oral or mechan- ical methods of emergency contraception, the availability of which may vary between districts and countries, depending on local laws and cultural or religious beliefs. Sexually transmitted infec- tions, including gonorrhoea, chlamydia, hepatitis B, and human immunodeficiency virus, are an important consideration in man- agement of victims of sexual assault. These are best prevented im- mediately by offering bacterial and viral prophylaxis, followed by sexual health screening 2 weeks later. Ideally, awareness of local prevalence of infections and resistance to antibiotics should decide treatment. Prophylaxis against HIV infection after sexual exposure should be discussed and offered in high-risk cases for up to 72 h after exposure, and in high-prevalence areas, this should be offered as a routine. How to perform a postmortem (where pathology services may be limited) The autopsy (postmortem examination) dates back to the 17th century. Over the years, this method of investigation has been re- peatedly proven to represent the gold standard for the diagnosis of various pathologies and confirmation of clinically suspected dis- eases. It is performed across the world, even where the most up-to- date resources and equipment for antemortem clinical diagnosis are readily available. While autopsy can involve extensive invasion of the body, it has evolved over the years and currently makes use of various adjunct methods of clinical investigations that are com- monly applied to the living. Who

performs the autopsy? Contrary to the general belief that a postmortem examination needs to be performed by a pathologist, it is evident when medicolegal practices are reviewed around the world that any doctor can be in- structed to undertake such procedure. The most noticeable excep- tion to this is if a postmortem is for a suspicious death or some other specific circumstance in law requires an ‘appropriately trained doctor’, in which case this will generally involve a forensic pathologist. In certain parts of the world where forensic and pathology re- sources are limited or inaccessible, groups of specialists from various branches of medicine and surgery could collaborate to perform an autopsy, thus supplementing each other’s breadth of knowledge and experience and providing a more rounded approach to any unex- pected findings in the case under question.

Section 27 Forensic medicine 6558 Types of autopsies There are various types of autopsies available to the pathologist, and these are selected based on the needs of the legal system, clinicians, and families or other interested parties. These include the following: • Full autopsy: while the expectation of a full autopsy is to dissect every part of the body, this most commonly used procedure in- volves opening the various body cavities and examining the major organs as detailed in ‘The organs’. • Limited autopsy: this is generally performed when a specific ques- tion or questions require answering that pertain to one part of the body, or in some cases an organ or structure, for example, this could include a chest-only examination or perhaps a heart-only examination. • Consented autopsy: a less common type of autopsy, mostly re- ferred to as a hospital autopsy, this type of examination is targeted to answer specific questions by the clinicians and family or other interested party. Although the purpose of this examination is well defined, this could be in the form of a full or limited examination, with the latter being the most common. • Medicolegal autopsy: this is perhaps the most common type of examination, its indications and procedures often determined by the relevant jurisdiction. • External examination: in some parts of the world an external examination alone is performed, and a cause of death reached on the balance of probabilities when the external findings are con- sidered along with the circumstances. The View and Grant system in Scotland is perhaps the best example of such type of examin- ation. The use of ancillary examinations as detailed later in this chapter in combination with the circumstances of death and the external findings generally provide a better insight into the exact cause of death. • Paediatric and fetal autopsy: this is a specialized procedure of fetuses, babies, and children and will not be considered in this chapter. Location and equipment Postmortem examinations have been undertaken over the years and around the world in a variety of locations, ranging from public arenas, teaching institutions, private houses, and (more recently) presented on national televisions and the Internet. The basic re- quirement for an autopsy procedure is a private room or building with good lighting (ideally natural), running water, and appropriate ventilation and drainage systems. Temporary mortuaries in the form of specialized tents and fridges are available and can be erected in a matter of hours. While these are commonly used in a setting of chemical, biological, or radionuclear contamination, they can also offer an appropriate setting for mass disasters and/or emergency autopsy work. Basic equipment such as a scalpel and/or postmortem knife, a pair of scissors, a brain knife, and forceps would perhaps be sufficient to undertake a full examination. The most challenging part of the examination is cutting through bone, particularly for opening the skull, but on occasions, opening the chest cavity can present prob- lems. While rotating and vibrating saws are commonly available, these are relatively expensive: a surgical handsaw is a cheaper and equally usable alternative. The autopsy procedure Examination of the body is generally divided into these main stages: • External examination • Internal examination • Ancillary investigation • Reconstruction A report is generally produced at the end of the

examination, and depending on local practices, a number of draft reports might be required prior to the final autopsy report. Equally, completion of a certificate of death can be required in some countries. This would typically be completed at the end of the dissection, or in some places at the time of the production of the final report. External examination Contrary to general belief, in some cases the external examination takes up the vast portion of time dedicated to the whole procedure, particularly in a forensic setting. This part of the examination targets first and foremost the findings required to identify the deceased as well as to record injuries, and would generally include the following: • Identification tags/procedure • Sex • Race • Age • Height • Weight • General external features: head hair and colour, eye colour, teeth, ears, fingernails and toenails, etc. • External marks: such as tattoos, scars, marks of medical interven- tion, jewellery, birth marks, etc. • Injuries: these can be divided into old and new, but are more often are listed from head to feet • Postmortem changes including rigor mortis, hypostasis, and decomposition Practice varies, but the gold standard is to record these findings in writing, supplemented with the use of body diagrams. The use of digital equipment such as digital voice recorders, tablets, and note- books is common practice. In general terms, it is advisable to keep a contemporaneous record of the findings at autopsy, particularly in a forensic setting, and that remains best done using a written format which represents perhaps the cheapest, most available, and secure way of doing this. Internal examination Once the external examination is completed, the internal examin- ation starts with exploring the head followed by opening the neck, chest, and abdomen. A number of approaches and incisions are available. For accessing the brain, the most commonly used access is via an incision starting behind one ear, extending to the top of the head, and ending behind the opposite ear. This can then be extended from either side to run along the posterior margins of the sterno-cleidomastoid muscles bilaterally and end at an intersecting point at the jugular notch, thus forming a ‘Y’-shaped incision over the neck. From then onwards, the incision follows the midline of the chest and abdomen, running to the left of the umbilicus and finishing at the

27.1 Forensic and legal medicine 6559 symphysis pubis. While this type of incision offers ready and easy access to the neck structure, one of the most important parts of the examination in a forensic setting, there are other incisions that re- sult in less obvious damage to the body. The most commonly used of these is the midline incision starting at the level of the thyroid cartilage, following the midline on the chest and abdomen, and ending at the symphysis pubis. An alternative is a curvilinear inci- sion across the top of the chest from one shoulder to the other with the lowest point just below the jugular notch, then complemented by a midline incision through the chest and abdomen also ending at the symphysis pubis. Skull and brain Once the skull is exposed, the scalp, muscles, and periosteum are in- spected. The temporal muscles are then dissected off the skull either by making a cut through the middle part and flapping the upper and lower parts, or through a curved incision of the upper part of the muscle, following its contour, and then dissecting it while leaving the lower muscle attached to the skull. An electric or handsaw is then used to open the skull cavity. This can be done in various ways, but a common approach includes cutting midway across the frontal bones anteriorly and the temporal bones at the sides, then extending the cutting line upwards along the parietal bones at a level centi- metres in front of the occipital protuberances. It is helpful to form a small triangle of bone at the midpoint, which can act as a stabilizing point for the skull cap when this is returned during the reconstruc- tion process. The dura is inspected after removal of the skull and carefully dis- sected to expose the underlying brain. The brain is then removed, starting at the frontal lobes by gently exposing the basal aspect and cutting through the cranial nerves. At the back, the tentorium is cut close to the bones, and

with the use of a thin and long scalpel the brainstem is cut across, thus releasing the brain and extracting it from the skull cavity. The dura is then fully removed, exposing the bone and offering an opportunity to identify any fractures. The body The remainder of the body is now examined. The soft tissue and muscles are gently dissected off the chest wall. The peritoneum is identified and cut through, thus opening the abdominal cavity, allowing the abdominal contents to be checked. Identifying a pneumothorax can be performed by either puncturing the chest in an area filled with water, or perhaps more easily by gently dissecting an area of intercostal muscles to expose the pleural lining, which is then pierced carefully with special attention to any hiss of air and lung collapse. Using the scalpel or knife, the sternoclavicular joints are released, followed by opening of the chest cavity through the costochondral joints using a saw or rib shears, thus exposing the chest structures. The pleural cavities are inspected. The major ves- sels are then cut obliquely at chest level. The neck muscles are then dissected one at a time by reflecting these towards the head and lat- erally. This is followed by palpation of the neck cartilages and bones. The jugular veins and carotid arteries are then inspected with the use of scissors. The muscles at the floor of the mandible are then cut along the inner aspect of the bone, thus releasing the tongue. It is prudent that at this point the larynx is expected for any obstruc- tion or disease. While gently holding the tongue and avoiding the laryngeal bones and cartilages, the neck structures are then dis- sected off the spine. Returning to the abdomen, the duodenum is identified, ligated, and then cut through. The bowels are then removed by dissecting these off the mesentery and cutting the distal bowel through the rectum. Blood for toxicology from the femoral veins can then be extracted, along with urine, if such examination is required. Once this is done, the bladder and internal genital organs can be released by dissecting these from the pelvic bones. The organs are now ready to be extracted en bloc from the body. This is performed by releasing all organs through dissecting the posterior soft tissues, with special attention to the dissection of the diaphragmatic connection to the chest cavity. The organs Once the organs are on the dissecting table, the approach to the examination varies, while the aim of the procedure remains the same: identifying the cause of death. This entails inspection of every structure and organ, generally by dissection and separation, remem- bering that one of the initial indications of pathology is the abnormal weight, size, and shape of the organ. Starting with the brain, the brainstem is cut at the level of the mid- brain then separated from the cerebellum. This is then serially cut to expose the main structures including the medulla and pons. The vermis is then separated and the lobes of the cerebellum serially cut. The cerebrum can then be serially cut at 1-cm intervals and the slices laid on the table, with special attention to keeping a check on the orientation and sidedness. The tongue is then serially sliced, the larynx inspected, and the la- ryngeal bones and cartilages dissected and checked for injury. The thyroid gland is identified and examined. The oesophagus is opened and dissected off the trachea, maintaining the gastro-oesophageal junction. The trachea and main bronchi are opened and inspected. The pericardium is opened and the pericardial sac content checked. The pulmonary artery is opened in situ and the cut is extended to the main branches. The aorta is cut through and inspected anteriorly and posteriorly down to include the abdominal part. The heart is then dissected off by cutting though its main connections to the body, fol- lowed by removal of both lungs through incisions across the hilum. The lungs are then examined by opening the airways and the blood vessels. The pulmonary tissue is then sliced through at regular intervals to inspect the parenchyma. Moving over to the heart, the coronary arteries are first examined by serially cutting through the vessels and the degree of stenosis, if any, is identified. Starting at the apex, serial transverse slices through the ventricles are then made up to midventricular level. Following the blood flow, the chambers of the heart are then opened and the valves inspected. Once this is

completed, the remaining ventricular muscle is sliced through. Further specialist examination of the heart can be performed if re- quired, including examination of the conduction system. Within the abdomen, the inferior vena cava is identified at the level of the liver and opened. The major branches from the abdom- inal aorta are then further examined. The adrenal glands are dis- sected and the kidneys exposed. These are then removed en bloc along with the ureters and the bladder. Examination of the kidneys is then performed through a longitudinal cut, with particular attention on the cortex, medulla, and pelvis.

Section 27 Forensic medicine 6560 The hemidiaphragms are removed. The pancreas is identified and cut through. This can also be removed en bloc along with the liver. The spleen is dissected off and serially sliced through. The stomach is opened and the patency of the biliary ducts checked. The liver is then dissected off, followed by opening the gall bladder. The liver parenchyma is then inspected by serially cutting the diaphragmatic surface of the liver. Ancillary investigations Depending on the circumstances and findings, a number of add- itional investigations could be performed. These include: • histology • toxicology • microbiology • biochemistry • immunology • organ retention and referral to specialists. Of these, the first two are the most common examinations. Histological sampling of the organs, in particular, is common prac- tice in many countries and provides a better insight into pathologies easily missed with the naked eye. There are no set rules about the extent of sampling, but it is generally accepted that the minimum requirement for a thorough examination is that a sample should be kept from each of the main parts/structures of the major organs. The use of toxicology and other investigations is considered on a case-by-case basis, and can offer the only way to identify the cause of death in some cases. Consideration of these is based on the cir- cumstances, experience of the operator, and readily available guide- lines issued by various scientific bodies around the world and readily available on the Internet. Reconstruction Once the procedure is completed, the organs are returned to the body and the various cavities closed. In some cases when organ retention is required, and depending on the system and family wishes, the body may only be released after the named organ is re- united with the body. Samples retained for ancillary investigations can also be returned to the body, or in some countries are kept indefinitely as part of the medical record of the deceased. It is very important to be aware of the local guidelines for tissue sampling and storage. Current trends in autopsy examination Radiological examination of the dead has advanced enormously over the last few years. CT is now perhaps the most talked about subject in forensic practice, where its uses have been mostly ex- trapolated from its well-established applications in the living. This also involves all applications of interventional radiology including coronary angiography and various uses of contrasts. In many cases, particularly catastrophic natural events such as a haemopericardium or intracranial haemorrhage, or with tu- mours, radiology can offer an accurate cause of death sufficient to certify death, while in other cases such as the common cor- onary artery disease and thrombosis, additional, arguably non- cost-effective, procedures such as angiography would be required to obtain the cause of death. In homicidal and traumatic causes of death, radiology still offers the best in situ and undisturbed picture of the internal findings and works well as an adjunct to invasive examination. Forensic use of medical biological tests Introduction Nearly all forensic scientists (and a large number of television watchers too) are familiar with the utility of SNPs (single nucleotides polymorphisms), a term used to describe a DNA sequence variation that occurs with relative frequency in the general population (>1%). Most SNPs have two alleles (one from the mother and one from the father). The practice of DNA ‘fingerprinting’, using SNP variations to identify specific individuals, first began in 1984. Since

1984, the role of genetic testing both in forensics and clinical medicine has ex- ploded beyond whatever could have been imagined. Genetic testing is likely to provide answers even when autopsy findings are said to be ‘nearly normal’ (meaning no significant le- sions are observed). Genetic testing is also used to explain why and how reasonable doses of some drugs may prove unexpectedly fatal. The number of such cases is substantial. Postmortem genetic testing of the major disease genes that cause long QT syndrome (LQTS) and catecholaminergic polymorphic ventricular tachycardia (CPVT) has revealed the presence of patho- genic mutations in up to 30% of sudden unexpected deaths and, to make things more complicated, multiple disease-associated genes are associated with each one of these syndrome. This brief section provides an overview of how modern genetic testing is used in the investigation of unexplained sudden death, whether by poisoning or as a consequence of previously unrecognized heart disease. Cardiac channelopathies The correct diagnosis of channelopathy is extremely important for two reasons. First, clinically, to prevent further deaths in relatives that may carry a similar genetic aberration. Second, forensically, to determine the actual cause of death when unnatural causes are sus- pected but no findings are apparent at autopsy. For a detailed discussion of cardiac channelopathies see Chapter 16.4, but with regard to forensic matters, many sudden death cases in younger people (<40 years), perhaps as many as half, go unexplained, with no gross findings identifiable at autopsy. This observation implies the presence of a genetic aberration, ei- ther inherited or acquired, usually of cardiac ion channels, which is difficult to identify because they are mostly low-penetrance dis- orders. In one recently published study of 35 patients with strong family histories of unexpected sudden death, candidates were thor- oughly screened (including arteriography) and then their DNA was studied with next-generation (‘NextGen’) sequencing (see ‘NextGen sequencing’). A firm diagnosis was made in more than half of the cases. Seven had Brugada syndrome, five had CPVT, thee had LQTS, two had early repolarization syndrome, and one had short QT syn- drome, yet five of those tested were phenotypically normal. Toxicogenetics Testing of drug-metabolizing enzymes may prove an equally valu- able tool as testing for channelopathies. It has been known for many years that some individuals metabolize drugs faster than others and, in most cases, the culprit enzymes (and by extension, the genes)

 are known. The problem had always been to identify which of the abnormal enzymes was present. There are clinical tests capable of distinguishing slow from fast metabolizers, but these are useless at autopsy. That problem, and many related problems, have been re- solved since the advent of modern genetic testing, when it became obvious that not only do enzymes have mutations, but so do drug receptors, such as the low-density lipoprotein receptor. A case study published in 2006 illustrated possible forensic ap- plications.
A breastfeeding mother had given birth with the aid of an episiotomy to a normal term infant. She was discharged with a prescription for codeine, as recommended at the time by most paediatric and obstetric organizations. Individuals capable of metab- olizing codeine normally convert approximately 10% of a given dose to morphine, which is why codeine is considered a mild narcotic. The mother was a professional woman with no medical history who did not use drugs, yet the child died of morphine poisoning on its 12th day of life. The child took no milk the day before it died and the mother, who used a breast pump, had saved all her milk from the day before death. Testing of the milk disclosed a concentration of morphine (70 ng/ml) that was many times normal. Genetic analysis disclosed that the mother was heterozygous for a gene mutation that caused her to be an ultrarapid metabolizer (CYP2D6*2A allele with a CYP2D6*2 × 2 gene duplication), converting most of the codeine she had ingested into morphine. The results were startling when exome (DNA

that contains coding information) sequencing data from 2203 African Americans and 4300 Caucasian Americans were recently examined by the National Heart, Lung, and Blood Institute in the United States of America for coding variation within the 12 cytochrome P450 (CYP) genes, the genes responsible for catalysing nearly 75% of all known phase I drug metabolic reactions (oxidation). As expected, many polymorphisms with known pharmacological effects were identified, but the aston- ishing finding was the presence of 730 novel nonsynonymous alleles (meaning that they would alter the amino acid sequence) across the 12 CYP genes It has been known for years that different people react to drugs differently. When a patient continues to complain of pain after being treated with an opiate, it may be that they cannot metabolize it. Similar considerations apply to many drugs. If the individual's me- tabolizer status is not known, the physician is forced to guess at the appropriate dosage, hence the push for the development of 'person- alized medicine'. The situation is no different in the postmortem set- ting, where the interpretation of postmortem drug concentrations poses an enormous problem. It is well established that postmortem drug concentrations tend to increase, depending on where in the body the blood is collected and the postmortem interval. High drug concentrations, unless astronomic, are often considered as artefacts. Another problem in interpreting postmortem drug concentrations is the complete overlap between therapeutic and lethal drug levels. Some of the overlap is explained by varying degrees of drug toler- ance, but it could just as well be due to enzyme polymorphisms. Practical forensic genetic testing Genetic arrays Twenty-three genes responsible for the most frequent types of channelopathies have been identified. Commercially available microarrays, designed to detect channelopathies and other abnormal genes (including hypertrophic cardiomyopathy), offer the quickest and most economical means of detection. Essentially, these arrays consist of a grid of known DNA sequences used to map other DNA, or even proteins. The principle is elegant but straightforward. After the DNA has been amplified, it is enzymatically digested into smaller pieces. Digested DNA is then placed onto a small glass slide coated with millions of microscopic 'beads'. Each bead represents just one gene and each is attached to a DNA 'probe' that will interact with the DNA segment being sought. The precise location and sequence of each spot is then recorded into a computer database. This approach is very useful for screening, because once a genetic variant has been identified, it is likely that nearby variants will be detected as well. NextGen sequencing Whole-exome NextGen sequencing is vastly more complex but also a vastly more powerful technique, which renders it possible to identify the subset of DNA that encodes protein (exons) and then sequence them using a new, very rapid technology (termed exome sequencing). This has been possible for nearly a decade, but the introduction of new techniques is driving the development of this methodology ever more quickly. Not just SNPs but other variants unique to the individual being studied may be revealed. Unlike like genotyping, gene sequencing can detect both known and unknown genetic variants, which raises difficulty in distinguishing pathogenic from nonpathogenic variants. It is possible that NextGen exome sequencing might be able to provide the cause of death in most cases where the autopsy is unrevealing. FURTHER READING Ackerman MJ, et al. (2011). HRS/EHRA expert consensus statement on the state of genetic testing for the channelopathies and cardio- myopathies: this document was developed as a partnership between the Heart Rhythm Society (HRS) and the European Heart Rhythm Association (EHRA). Europace, 13, 1077–109. Bagnall RD, et al. (2014). Exome analysis-based molecular autopsy in cases of sudden unexplained death in the young. Heart Rhythm, 11, 655–62. Burton J, Rutty G (2010). The hospital autopsy: a manual of funda- mental autopsy practice, 3rd edition. CRC Press, London. Burton J, et al. (2015). Atlas of adult autopsy pathology. CRC Press, London. Cybulska B (2013). Immediate medical care after sexual assault. Best Pract Res Clin Obstet Gynaecol, 27, 141–9. Den Otter JJ,

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