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REVIEW ARTICLE

# Consent and anaesthetic risk

**K. Jenkins and A B. Baker***

*Department of Anaesthetics, University of Sydney, Royal Prince Alfred Hospital, Missenden Road, Camperdown, Sydney, NSW 2050, Australia*

**Summary**

The incidences of mortality and morbidity associated with anaesthesia were reviewed. Most of the published incidences for common complications of anaesthesia vary considerably. Where possible, a realistic estimate of the incidence of each morbidity has been made, based on the best available data. Perception of risk and communication of anaesthetic risk to patients are discussed. The incidences of anaesthetic complications are compared with the relative risks of everyday events, using a community cluster logarithmic scale, in order to place the risks in perspective when compared with other complications and with the inherent risks of surgery. Documentation of these risks and discussion with patients should allow them to be better informed of the relative risks of anaesthetic complications. Depending on specific comorbidities and the severity of operation, these risks associated with anaesthesia may increase for any one individual.

**Keywords** *Anaesthesia*; risk. *Complication*; incidence, mortality, morbidity, perioperative.

*Correspondence to: A. B. Baker*
*E-mail: bbaker@usyd.edu.au*
**Present address: North Bristol NHS Trust, Southmead Hospital, Bristol, UK*
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*'That which is necessary is never a risk' Paul de Gondi.*

The legal interpretation of the acceptable practice of medicine was changed markedly in Australia by the Rogers v Whitaker [1] decision that overturned the notion of the 'reasonable doctor' as enumerated in traditional British law by the Bolam Principle [2]. This decision was subsequently confirmed by another case, Chappel v Hart [3, 4]. The Australian National Health and Medical Research Council (NHMRC) has also firmly stated that 'Known risks should be disclosed when an adverse outcome is common even though the detriment is slight, or when an adverse outcome is severe even though its occurrence is rare', and 'Complex interventions require more information, as do interventions where the patient has no illness' [5]. Even in Britain, there are winds of change blowing, with recent professional guidelines from the General Medical Council [6] stating that 'existing caselaw gives a guide as to what can be considered minimum requirements of good practice', and that patients 'must be given sufficient information, in a way that they can understand, in order to enable them to make informed decisions about their care'. These legal concepts have recently undergone further change following Rosenberg v Percival [7], when the High Court of Australia said: 'The more remote the contingency which a doctor is required to bring to the notice of a patient, the more difficult it may be for the patient to convince a court that the existence of the contingency would have caused the patient to decide against surgery'. These decisions have meant that anaesthetists have to decide which anaesthetic risks to declare to patients, and what incidences to quote for those declared risks. The actual risks of anaesthesia are not readily listed anywhere, and those complications that have been recorded often have widely differing variances in different studies. Even with the certain end-point of death, there are varying interpretations as to whether or not anaesthesia was the sole cause or was only contributory [8, 9]. In any event, anaesthetists tend to be ignorant of the overall published mortality figures at one month for patients undergoing

elective surgery of 1:177 (∼1:200), or of 1:34 (∼1:40) for emergency surgery [10].

In an endeavour to improve this situation, we surveyed the literature and compiled a listing of the risks of anaesthesia for a variety of anaesthetic complications and side effects. The choice and incidence of complications have been influenced by the available literature, and to some extent the inherent risks will be a result of the type of practice that those authors had. As in the literature on medical and surgical risk assessments, anaesthetic literature is more likely to represent best practice than worst practice, and to be the experience of practitioners who are commonly performing the procedures rather than infrequent practitioners of any particular procedure.

## Methods

A Medline® search of the literature was conducted via PubMed®, from 1966 to date, for all publications concerned with peri-operative risk and complications associated with anaesthesia. This computerised search identified keywords in the title, abstract and medical subject headings (MeSH). In addition, the 'related articles' feature of PubMed® was used to identify other relevant publications. Key words included anaesthesia/anaesthesia, risk, peri-operative, postoperative, complications, mortality and morbidity. Specific complications were also sought, such as cardiac arrest, respiratory, cardiovascular and neurological complications, awareness, anaphylaxis, ocular complications, deafness, regional anaesthesia morbidity and minor morbidity (pain, postoperative nausea and vomiting, sore throat, headache, drowsiness, dizziness and dental damage). Reference lists from appropriate selected publications were hand searched to identify additional relevant articles.

## Results

Traditional measures of adverse outcome in anaesthesia may be divided crudely into peri-operative mortality and morbidity.

### Mortality

Anaesthetic-related mortality is rare. Although death is a clearly definable end-point, epidemiological studies of peri-operative mortality over the last 50 years vary in their objectives, study design, populations, definitions and time span, leading to difficulties in comparing studies. In addition, the denominator data are most often only estimated and are often unreliable, whereas the numerator will often be under-reported, particularly in situations with potential medicolegal implications. Table 1 summarises these studies [8, 9, 11–34].

Total peri-operative mortality is not insignificant, with 30-day mortality rates in the UK quoted in 2000 as 1:34 (2.94%) after emergency surgery and 1:177 after elective surgery (0.56%) [10, 35]. However, the contribution of anaesthetic-related mortality is now considered to be < 10% of total operative mortality. Studies of anaesthetic-related mortality in the 1950s reported an incidence of 2.5–6.4:10 000 deaths [11, 21, 36]. Since then, data from South Africa have shown a decrease from 4.3:10 000 anaesthetic-related deaths (1956–71) to 0.7:10 000 (1972–87) [21]; from 1:5500 to 1:20 000 in New South Wales (NSW), Australia, from 1960 to 1990 [25], and from 0.3:10 000 to 0.13:10 000 for the whole of Australia from 1985 to 1999 [9, 25]. These Australian figures exemplify the difficulties inherent in such statistics, as the NSW rate (with compulsory Coroner reporting for all deaths within 24 h of anaesthesia and surgery) is given as 1:66 183 in the Australia and New Zealand College of Anaesthetists (ANZCA) report [9], yet the number of procedures estimated by the NSW Committee for the same period is approximately half those calculated by the ANZCA report (J Warden & R Holland pers. commun.), thus bringing the incidence more into line with other recent NSW reports [25]. The UK Confidential Enquiry into Peri-Operative Death (CEPOD) in 1987 estimated the risk of death within 30 days solely due to anaesthesia as 1:185 000 [8]. Some authors now quote the incidence of death due to anaesthesia in ASA physical status I and II patients as ∼1:100 000 (range 1:2500–1:185 000) [8, 20] with risk increased 5–10 times for high-risk patients and emergency surgery [37]. This improvement in mortality may be attributed to several factors: better general medical care in the community; changes in anaesthetic drugs and techniques; better staffing, supervision and training; improvements in monitoring and peri-operative care; changes in surgical techniques; continuing medical education, including the recognition of preventable hazards through mortality surveys.

National studies of mortality that assess the quality of the delivery of care continue to highlight factors that contribute to anaesthetic-related mortality: inadequate pre-operative assessment, preparation and resuscitation; inappropriate anaesthetic technique; inadequate peri-operative monitoring; lack of supervision; poor postoperative care [25, 35, 38].

Mortality studies in the outpatient population reflect the safety profile of anaesthesia for this group. Warner *et al.* [39] studied 38 598 patients having 45 090 procedures and reported four deaths within one month of surgery, comprising two from road traffic accidents and two from myocardial infarction (nonaccidental death rate 1:22 546). Other large studies report no peri-operative deaths in the ambulatory population [40–43].

**Table 1** Studies of anaesthetic and peri-operative mortality.

| Author | Location | Study Period | Number of Procedures | Deaths | Deaths:10 000 |
|---|---|---|---|---|---|
| Beecher & Todd [11] | 10 university hospitals, USA 1948–1952 | Hospital stay | 599 548 | 7977 | 133.1 total<br>6.4 anaesthesia-related |
| Vacanti *et al.* [12] | | 48 h | 68 388 | | ASA1 8 total<br>ASA5 940 total |
| Marx *et al.* [13] | Bronx Municipal hospital New York, US | 5 days | 34 145 | 645 | 189 total |
| Hovi-Viander [14] | 100 Finland | 3 days | 338 934 | 626 | 18 total<br>2 anaesthesia-related |
| Turnbull *et al.* [15] | General Hospital, Vancouver, Canada | 48 h | 195 232 | 423 | 22 total<br>2 preventable anaesthesia-related |
| Lunn & Mushin [16] | 5 regions in UK | 6 days | 1 147 362 | 3736 | 62.5 total<br>5.9 anaesthesia-related<br>1 attributed to anaesthesia |
| Gibbs [17] | 1979–1984 | Hospital stay | 1 100 000* | | 0.5 anaesthesia-related |
| Buck *et al.* [8] | 3 NHS regions | 30 days | 555 168 | 1:185 056 solely attributed to anaesthesia | 70 total<br>7.7 anaesthesia-related |
| Tiret *et al.* [18] | 460 French public and private hospitals 1978–1982 | 24 h | 198 103 | 67 (16 coma) | 4.2 total<br>1.26 anaesthesia-related |
| Olsson & Hallen [19] | 1967–1984 | 7 days | 250 543 | | 2.4 total<br>0.4 anaesthesia-related |
| Pederson & Johansen [20] | Prospective 1 year study | | 7306 | | 4 attributed to anaesthesia |
| Harrison [21] | Groote Schur Hospital, Cape Town, South Africa, 1956–1987 | 24 h | 782 182 | | 18.3 total<br>1.9 anaesthesia-related |
| NH & MRC [22] | Australia 1985–1987 | 2 days | 5 470 000* | | 0.3 anaesthesia-related |
| NH & MRC [23] | Australia 1988–1990 | 2 days | 7 800 000* | | 0.2 anaesthesia-related |
| Wang & Hagerdal [24] | 1979–1989 | 24 h | 262 850 | | 0.3 anaesthesia-related |
| Warden *et al.* [25] | Australia 1984–1990 | 24 h | 3 500 000* | 1503 | 4.4 total<br>0.5 anaesthesia-related |
| Tikkanen & Hovi-Viander [26] | Finland 1986 | Hospital stay | 325 585 | | 17.5 total<br>0.2 anaesthesia-related |
| McKenzie [27] | Zimbabwe teaching hospital 1992 | 24 h | 34 553 | 89 | 25.8 anaesthesia-related<br>3.3 avoidable anaesthetic |
| Eagle & Davis [28] | Western Australia 1990–1995 | 48 h | 166 000 per year* | | 6 total<br>0.25 anaesthesia-related |
| ANZCA [29] | Australia 1991–1993 | 2 days | 7 800 000* | 116 | 0.15 anaesthesia-related |
| ANZCA [30] | Australia 1994–1996 | 2 days | 8 500 000* | 135 | 0.16 anaesthesia-related<br>0.067 attributable to anaesthesia |
| NHSE [31] | NHS performance indicators 1998:1999 | 30 days | 2 300 000 | 32 956 | 140 emergency total<br>50 elective total |
| Arbous *et al.* [32] | Prospective study 1995–1997 | 24 h | 869 483 | 811 | 8.8 total<br>1.4 anaesthesia-related |
| Kawashima *et al.* [33] | Training hospitals, Japan 1999 | 7 days | 793 840 | | 7.19 total<br>0.13 attributable to anaesthesia |
| Kawashima *et al.* [34] | Training hospitals, Japan 2000 | 7 days | 941 217 | | 7 total<br>0.1 attributable to an anaesthesia |
| ANZCA [9] | Australia 1997–1999 | 2 days | 10 336 000 | 130 | 1:79 509 anaesthesia-related<br>0.13 attributable to anaesthesia |

*Estimated.
NH & MRC = National Health & Medical Research Council; NHSE = National Health Service Executive; ANZCA = Australian and New Zealand College of Anaesthetists.

The UK Confidential Enquiry into Maternal Deaths (CEMD) has recorded mortality in pregnant women since 1952. The direct death rate associated with Caesarean section has decreased from 4 :1000 (1952–54) to $\sim$ 0.1:1000 in the last triennium (1997–99) [44]. Improvements in maternal safety in the UK have taken place in association with the development of specialist obstetric anaesthesia services and a move towards the increased use of regional anaesthesia. The contribution of anaesthesia to peri-operative maternal mortality in the UK

has been recorded since 1970. Of the 104 anaesthetic deaths reported since then, 75% were associated with emergency procedures and 25% with elective procedures; 96% were associated with general anaesthesia [44]. Maternal mortality rates in the developing world are much higher, with sub-Saharan Africa recording average mortality rates of 100 times that in the UK (980:100 000 live births) [45, 46]. In South Africa, a confidential enquiry into maternal deaths noted that anaesthetic accidents contributed to 5% of maternal deaths, with complications resulting from general anaesthesia, particularly difficult or failed tracheal intubation, being the commonest cause [47].

The risk of peri-operative death increases with age. Jin and Chung quoted an overall mortality rate of 1.2% within 30 days of surgery for the general population. This increased to 2.2% in 60–69 years olds, 2.9% in 70–79 years olds, 5.8–6.2% in those aged > 80 years and 8.4% in those aged > 90 years. Major surgery further increases this risk, leading to a 19.8% mortality rate in the latter group [37,48–51]. The 1999 CEPOD report found that > 90% of peri-operative deaths were in the over 60s, with 38% in those aged > 80 years. The majority of these procedures were urgent or emergencies (65%) in a high-risk population (84% ASA physical status III or higher). Most elderly patients underwent general (42%), orthopaedic (22%) or vascular (14%) procedures [52]. As the elderly constitute a growing proportion of the elective and emergency surgical workload, anaesthetists need to be aware of their higher risk of morbidity and mortality in order to ensure optimal peri-operative care.

Mortality rates associated with anaesthesia in children have decreased steadily from 1.8–3.3:10 000 in the 1960s to 0.18–0.25:10 000 by 1990 [53].

## Morbidity

Anaesthetic morbidity ranges from major permanent disability to minor adverse events causing distress to the patient but no long-term sequelae. As with studies of mortality, there is a lack of uniformity in reporting peri-operative adverse events between institutions and countries. Criteria for reporting vary enormously, from limited details due to medicolegal necessity [54] to comprehensive computerised data acquisition for national benchmarking processes [55]. Table 2 summarises some of the larger studies of intra-operative and recovery adverse events in both ambulatory patients and inpatients [48, 55–67]. Both the methods of data acquisition and definitions of criteria for adverse events differ between studies, making comparisons difficult. Other methods of investigation have been established to examine closed legal claims and critical incidents or sentinel events in anaesthesia. These national studies highlight problems or system failures and recommend improvements in patient care [38, 44, 54, 68, 69].

## Cardiac arrest

The incidence of peri-operative cardiac arrest has decreased significantly over the last 25 years (Table 3) [14, 19, 24, 33, 34, 56, 70–77]. Keenan *et al.* noted that the cardiac arrest rate halved over two decades at their institution (21:10 000 in 1969–1978 vs 1.0:10 000 in 1979–1984), predominantly because of a decrease in respiratory complications [73]. Most studies in the last 10 years quote incidences of anaesthesia-related cardiac arrest of 0.12–1.4:10 000, with associated mortality rates of 0.06–0.6:10 000 [24, 33, 34, 76, 77]. Morray's study of children quotes a similar incidence (1.4:10 000), with 55% of events occurring in infants less <1 year old [75]. The commonest causes of cardiac arrest included

**Table 2** Studies of intra-operative and immediate postoperative morbidity.

| Author | Study period | No. of Procedures | Intra-operative events (%) | Recovery events (%) |
|---|---|---|---|---|
| Cohen *et al.* [56] | 1975–1978 | 52 197 | 7.6 | 3.1 |
| | 1979–1983 | 60 524 | 10.6 | 5.9 |
| Cooper *et al.* [57] | 1985–1986 | 12 088 | 13.8 | 7.1 |
| Zelcer & Wells [58] | Nov 1985 | 443 | | 30.0 |
| Pederson *et al.* [48] | 1986–1987 | 7306 | 4.5 | 7.4 |
| Hines *et al.* [59] | 1986–1989 | 18 473 | 5.1 | 23.7 |
| Moller *et al.* [60] | 1989–1990 | 20 802 | 14.9 | 13.5 |
| Rose *et al.* [61] | 1991–1993 | 24 157 | | 1.3 respiratory |
| Ouchterlony *et al.* [62] | 1985–1988 | 1361 | 18.7 | 47.4 |
| Schwilk *et al.* [63] | | 18 350 | 23.2 (1.2 serious) | |
| Hunter & Molinaro [64] | 1990–1994 | 1126 | 2.3 | |
| Schwilk *et al.* [65] | | 26 907 | 27.9 (0.9 serious) | |
| Chung *et al.* [66] | 3 years | 17 638 | 4.0 | 9.6 |
| Bothner *et al.* [55] | 1992–1997 | 96 107 | 22 overall peri-operatively (1.0 serious) | |
| Fasting & Gisvold [67] | 1996–2000 | 83 844 | 15.7 | |

**Table 3** Studies of peri-operative cardiac arrest.

| Author | Study period | Procedures | Cardiac arrest | Remarks |
|---|---|---|---|---|
| Hovi-Viander [14] | 1975 Finland | 338 934 | 3:10 000 | |
| Pottecher *et al*. [70] | 1978–1982 France | | 6:10 000 | 3.5:10 000 anaesthesia-related mortality rate |
| Cohen *et al*. [56] | 1975–1983 Canada | | 7.1:10 000 recovery | |
| Olsson & Hallen [19] | 1967–1984 | 250 543 | 6.8:10 000 | 0.3:10 000 anaesthesia-related mortality<br>2.4:10 000 overall mortality |
| Pederson *et al*. [71] | Prospective | 7306 | 10.9:10 000 intra-operative | |
| Aubas *et al*. [72] | 1983–1987 France | 102 468 | 2.8:10 000 anaesthesia-related | 1.1/10 000 anaesthesia-related 1.2 mortality rate |
| Keenan & Boyan [73] | 1969–1978<br>1979–1988 | 241 934 | 2.1:10 000<br>1.0:10 000 | 0.8:10 000<br>1:10 000 due to respiratory cause |
| Wang & Hegerdal [24] | 11 years | 262 850 | 0.04:10 000 intra-operative<br>0.08:10 000 recovery | |
| Auroy *et al*. [74] | 5 months, France | 103 730 (regional anaesthesia) | 3.1:10 000 total<br>6.4 (1.2):10 000 in spinals | 23% fatal in spinals |
| Morray *et al*. [75] | Multicentre POCA <18 years old | | 1.4 (0.45):10 000 related to anaesthesia | 26% fatal<br>55% <1 year old |
| Biboulet *et al*. [76] | 6 years, France | 101 769 | 1.1:10 000 | 0.6:10 000 anaesthesia-related mortality rate |
| Kawashima *et al*. [33] | 1999, Japan training hospitals | 793 840 | 6.53:10 000 total<br>0.78:10 000 attributable to anaesthesia | 0.1:10 000 anaesthesia-attributed mortality rate |
| Kawashima *et al*. [34] | 2000, Japan training hospitals | 941 217 | 6.52:10 000 total<br>0.53:10 000 attributable to anaesthesia | 0.06:10 000 anaesthesia-attributed mortality rate |
| Newland *et al*. [77] | 1989–1999 | 72 959 | 1.37:10 000 contributory anaesthesia<br>0.69:10 000 attributable to anaesthesia | 0.55:10 000 anaesthesia-attributed mortality rate |

POCA: Paediatric peri-operative cardiac arrest register.

medication-related events, cardiovascular causes including hypovolaemia, and poor airway management. In patients undergoing regional anaesthesia, including spinal, epidural, peripheral nerve blocks and intravenous regional anaesthesia, the overall cardiac arrest rate has been quoted at 3.1:10 000. Spinal anaesthesia alone accounted for 6.4:10 000 events, of which 23% were fatal [74].

## Respiratory complications

Postoperative respiratory complications, such as pneumonia, remain a major cause of surgical morbidity and mortality [78]. The contribution, if any, of anaesthesia to these events is not often recorded. Respiratory complications due to anaesthesia are more commonly those acute events closely associated in time to the operation. Engelhardt & Webster [79] recently reviewed pulmonary aspiration of gastric contents associated with anaesthesia. The incidence of this complication in the general surgical population has been reported in three large studies. Olsson *et al*. [80] found an aspiration incidence of 1:2131 during anaesthesia in 185 385 patients, with a mortality rate of 1:45 454. Forty-seven per cent of the patients who aspirated developed pneumonitis and 17% required lung ventilation. A retrospective review of > 200 000 patients in the Mayo Clinic revealed an aspiration rate of 1:3216, with a mortality rate of 1:71 829 [81]. In a study of 85 594 adult surgical patients by Mellin-Olsson *et al*. [82] the incidence of pulmonary aspiration was 2.9:10 000, all in patients undergoing general anaesthesia. The incidence was four times greater in emergency cases. In 30 199 patients undergoing regional anaesthesia, none aspirated.

In children, the risk of regurgitation and pulmonary aspiration may be greater but it is rarely associated with pneumonitis [79, 83]. Large studies have reported an incidence between 1:10 000 ($n = 40\ 240$) and 10:10 000 cases ($n = 50\ 880$), with no associated deaths or serious morbidity [84, 85]. Aspiration occurred more frequently in patients with poorer ASA physical status (III or IV) and in emergency cases.

With regard to obstetric anaesthesia, patients undergoing Caesarean section under general anaesthesia have at least twice the risk of pulmonary aspiration when compared with the general population. Two Italian studies quoted an incidence of aspiration between 1:1431 and 1:1547, whereas a more recent study reported aspiration in 1:900 patients undergoing Caesarean section [86–88]. There were no fatalities in this group.

The reported incidence of a Cormack and Lehane grade 3 or 4 view at laryngoscopy is 2–8%. Difficulty with tracheal intubation (defined as three or more attempts) in general surgical patients is reported as occurring in 1.15–3.8% of patients, with failure to intubate the trachea seen in 0.13–0.3%. Inability to intubate a patient's trachea or ventilate a patient's lungs happens much less commonly, and is estimated to occur in 1–3:10 000 cases [89]. In the obstetric population, the incidence of difficult or failed tracheal intubation is more common, reported at between 1:250 and 1:300 patients, presumably due to anatomical and physiological airway changes and, more recently, the relative lack of training opportunities in obstetric general anaesthesia [90–92].

**Table 4** Goldman's Cardiac Risk index [96].

| Criteria | Points |
|---|---|
| Age >70 years old | 5 |
| Myocardial infraction within six months | 10 |
| S3 gallop or raised jugular venous pressure | 11 |
| Important aortic stenosis | 3 |
| Rhythm other than sinus or premature atrial contractions | 7 |
| >5 premature ventricular contractions per minute before surgery | 7 |
| Poor general medical status | |
| $P_aO_2$ <8.0 kPa or $P_aCO_2$ >6.7 kPa | |
| Potassium <3.0 mmol.l$^{-1}$ or bicarbonate <20 mmol.l$^{-1}$ | |
| Urea >18 mmol.l$^{-1}$ or creatinine >240 mmol.l$^{-1}$ | |
| Abnormal aspartate transaminase | |
| Signs of chronic liver disease | |
| Bedridden from non-cardiac causes | 3 |
| Intraperitoneal, intrathoracic or aortic operation | 3 |
| Emergency operation | 4 |
| **TOTAL** | **53** |

| Points | Group | Life-threatening complications (%) | Mortality (%) |
|---|---|---|---|
| 0–5 | I | 0.7 | 0.2 |
| 6–12 | II | 5 | 1.5 |
| 13–25 | III | 11 | 2.3 |
| 26–53 | IV | 22 | 56 |

## Other cardiovascular complications

Peri-operative myocardial infarction (MI) has been recognised as a major problem since the 1950s [93]. Recent MI and congestive cardiac failure were two early risk factors identified as being associated with peri-operative MI. Shah *et al.* [94] reported that the peri-operative MI rates were 5% if the time from MI to operation was > 6 months, 15% if between 3 and 6 months, and 37% if < 3 months. In a study by Rao *et al.* [95] in which patients with a previous MI were aggressively monitored and managed peri-operatively, lower peri-operative morbidity and mortality rates were produced. Re-infarction occurred in 5.7% of patients who were 0–3 months after an MI, and in 2.3% of patients who were 4–6 months after an MI.

Pre-operative predictors of cardiovascular risk in non-cardiac surgery have been identified, notably in Goldman *et al.*'s cardiac risk index [96], Detsky *et al.*'s [97] modified cardiac risk index (incorporating unstable angina, history of pulmonary oedema and Canadian Cardiovascular Society angina classes III and IV), and more recently Lee *et al.*'s [98] revised cardiac risk index derived from 4315 patients undergoing major noncardiac procedures in a teaching hospital. Goldman *et al.*'s criteria and risk stratification for elective noncardiac surgery are summarised in Table 4. Lee *et al.*'s study [98] found that major cardiac complications occurred in 2% of patients in the derivation cohort (56:2893). The six independent predictors of complications were: high-risk surgery, history of ischaemic heart disease, history of congestive cardiac failure, history of cerebrovascular disease, pre-operative treatment with insulin, pre-operative serum creatinine >166 μmol.l$^{-1}$. Combining the derivation and validation cohorts, rates of major cardiac complication with 0, 1, 2 or ≥3 of these factors were approximately 0.5, 1, 5 and 10% respectively (Table 5) [99].

The American College of Cardiologists and the American Heart Association have published guidelines for peri-operative cardiac evaluation of patients undergoing noncardiac surgery [100]. They classified minor, intermediate and major clinical predictors of risk for MI, cardiac failure and peri-operative death that are summarised in Table 6, but gave no indication of the relative risks.

Risks for invasive monitoring depend on the type of monitoring and the site of access. Scheer *et al.* [101] reviewed complications associated with peripheral arterial catheters in anaesthesia and intensive care and found that major complications, such as permanent ischaemic damage, sepsis and pseudo-aneurysm formation, occurred in < 1% of cases. Temporary arterial occlusion occurred in 1.5–35% (mean 19.7%) of radial arteries in which catheters had been placed, and in 1.45% of femoral arteries. They suggested that risk increases with an increase in catheter diameter and if duration of cannulation is > 48 h. Local site infection occurred in 0.74% of radial arteries and 0.78% of femoral arteries. Duration of cannulation > 96 h was associated with an increased risk of infection. Cannulation of the ulnar artery had a similar complication rate to radial artery cannulation.

**Table 5** Lee's revised cardiac index [98, 99].

| Major medical risk factors for noncardiac surgery | | | | | |
|---|---|---|---|---|---|
| | | Actual rates of cardiac complications % [range] | | | Approximate rates of cardiac complications |
| No. of simple cardiac risk factors | Revised cardiac risk index | Ref. 98 | Ref. 99 | | |
| | | | No blocker | Blocker | No blocker |
| 0 | Class I | 0.4 [0.05–1.5] | 1.0 [0.6–1.9] | 0.4 [0.1–0.9] | ~ 0.5% |
| 1 | Class II | 0.9 [0.3–2.1] | 2.2 [1.4–3.3] | 0.8 [0.3–1.7] | ~ 1.0% |
| 2 | Class III | 6.6 [3.9–10.3] | 4.5 [3.2–6.3] | 1.6 [0.8–3.3] | ~ 5.0% |
| 3 | Class IV | 11.0 [5.8–18.4] | 9.2 6.5–13] | 3.4 1.7–6.7] | ~ 10.0% |
| 4 | Class V | | 18 [12–20] | 7.0 [3.4–14] | ~ 15.0% |
| =5 | Class VI | | 32 [19–47] | 14 [6.5–27] | ~ 30.0% |

Simple risk factors: High-risk surgery; ischaemic heart disease; congestive cardiac failure; cerebrovascular disease; insulin-dependent diabetes; creatinine >170 mmol.l$^{-1}$.

**Table 6** Clinical predictors of increased peri-operative cardiovascular risk [100].

| Major | Intermediate | Minor |
|---|---|---|
| Unstable coronary syndromes | Mild angina pectoris | Elderly patients |
| Decompensated congestive heart failure | Compensated or prior congested heart failure | Low functional capacity (< 4 metabolic equilvalents) |
| Significant symptomatic arrhythmias | Prior myocardial infarction | Non-sinus rhythm |
| Severe valve disease | Diabetes mellitus | Stroke history |
| | Renal insufficiency | Uncontrolled hypertension |
| | | Abnormal electrocardiogram |

Deaths have been reported after central venous cannulation with an incidence of up to 1:252 using infraclavicular subclavian lines [102]. A subsequent series reported no deaths in 13 800 patients after central venous cannulation [103]. The incidence of pulmonary artery perforation has been quoted as 0.06% in a series of 6245 patients [104]. Looking at nonfatal complications, Ruesch *et al.* [105] analysed 17 prospective comparative trials of internal jugular vein ($n = 2085$) and subclavian vein ($n = 2428$) cannulation. Arterial puncture was more common with internal jugular catheters (3 vs. 0.5%), as was bloodstream infection (8.6 vs. 4%). Malposition of the venous catheter was seen more commonly via the subclavian route (9.3 vs. 5.3%), as were haemopneumothorax (1.5 vs. 1.3%) and vessel occlusion (1.2 vs. 0%). Comparing the subclavian route with the femoral venous route in critically ill patients, femoral lines caused a higher incidence of infections (19.8 vs. 4.5%) and thrombotic complications (21.5 vs. 1.9%) [106].

A meta-analysis of trials looking at the effect of ultrasound guidance suggested that real-time ultrasound guidance improved success rates and decreased complications associated with internal jugular and subclavian vein catheter placement when compared with anatomical landmark techniques for placement [107].

The incidence of peripheral venous thrombophlebitis was studied extensively in the 1970s and 1980s when intravenous preparations of drugs solubilised in propylene glycol and 'Cremophor EL' were available. In a study of 519 patients, venous sequelae were reported in 12% of patients receiving diazepam alone or fentanyl and methohexital [108]. Other authors have reported thrombophlebitis in 24–43% patients given etomidate and in 4–23% of those given thiopental [109, 110]. A review by Clarke [111] suggested that venous sequelae depended on the solubilizing agent, with the frequency of complications in water-soluble and Cremophor EL-based anaesthetics varying between 5 and 10%. Diazepam or etomidate dissolved in propylene glycol could produce venous reactions in > 25% of patients.

### Postoperative neurological dysfunction

In the elderly surgical patient, postoperative cognitive dysfunction (POCD), most commonly manifested as a lack of concentration and problems with memory, may persist for a long period. The ISPOCD1 multicentre study looked at 1218 patients aged > 60 years undergoing major abdominal, thoracic or orthopaedic surgery [112]. There was a 26% incidence of POCD at one week after surgery and a 10% incidence at three months after surgery, compared with 3.4 and 2.8% in controls. Risk factors identified for early POCD included increasing age, duration of anaesthesia, limited education, second operation, postoperative infections and respiratory

complications. Only age was found to be a risk factor for late POCD. There was no difference in long-term cognitive function between patients having general or regional anaesthesia [113]. Follow-up at 1–2 years showed that POCD is a reversible condition in the majority of patients, but may persist in ~ 1% [114].

The reported incidence of peri-operative delirium varies widely due to differences in diagnostic criteria. Up to 14% of general surgical patients develop postoperative delirium, with the risk increasing to 40% if intensive care is required [115, 116]. Another study showed a 44% incidence of delirium in the elderly after fixation of a fractured neck of femur [117, 118]. Significant risk factors for postoperative delirium include increasing age and poor medical condition. After 75 years of age, there is a threefold increased risk of developing postoperative delirium [115].

The incidence of peri-operative cerebrovascular accident (CVA) varies between 0.08 and 2.9% in general surgical patients, and is as much as 4.8% in patients undergoing head and neck surgery, with a reported mortality rate of 46%. As a reference point, the annual incidence of stroke in the UK is 0.1–0.2% [116, 119]. Most peri-operative CVAs occur between the second and tenth postoperative day (mean = seventh day). Risk factors include advancing age, previous cerebrovascular disease (10-fold increased risk), hypertension (fourfold increased risk), peripheral vascular disease, chronic obstructive airways disease, atrial fibrillation, carotid artery stenosis and obstructive sleep apnoea. The incidence of peri-operative CVA in a patient with a previous stroke is 2.1%, with an associated increased risk of mortality of 60% [116].

The risks associated with carotid endarterectomy have been recently summarised in a review by Barnett *et al.* [120]. Several randomised controlled trials were published in the 1990s comparing best medical treatment with best medical and surgical treatment [121–123]. The combined risk of stroke and death within 30 days of surgery was 6.2% in symptomatic patients and 4.4% in asymptomatic patients [122, 123]. The risk of a disabling peri-operative CVA or death was 2.1%, the majority occurring within 24 h. Cranial nerve injuries (involving the facial nerve, superior laryngeal branch of vagus nerve, spinal accessory nerve or hypoglossal nerve) were seen in up to 6.8% of patients [120]. When cerebral angiography was used, 0.6% of the 2885 patients in the North American Symptomatic Carotid Surgery Trial had nondisabling strokes within 24 h, and an estimated 0.1% suffered disabling strokes [120, 124, 125].

## Awareness

The fear of awareness is common in patients, with up to 54% concerned about waking up during their surgery [126]. In the 1970s, anaesthetic studies using 60–70% nitrous oxide alone as a maintenance anaesthetic showed incidences of awareness in up to 7% of patients [127]. More recently, the incidence of conscious awareness with explicit recall and severe pain has been estimated at < 1:3000 general anaesthetics [128]. Conscious awareness with explicit recall but without pain is more common, with a reported incidence of 0.1–0.7% [128–130]. Most large clinical studies nowadays estimate the risk of explicit awareness as < 0.3% [127]. The incidence may be increased in general anaesthesia using neuromuscular blockade compared with general anaesthesia without paralysis (0.18 vs. 0.1%) [130]. A study using total intravenous anaesthesia with neuromuscular blockade in 1000 patients reported an incidence of awareness of 0.2% [131]. Cases of awareness come not only from cardiac surgery and obstetrics, but also from all surgical specialities. After surgery, patients who experience intraoperative awareness may develop a post-traumatic stress disorder, particularly those patients who have experienced severe pain. The Australian Incident Monitoring Study recently reviewed 81 cases of awareness and found the commonest causes to be drug error resulting in inadvertent paralysis of an awake patient, and failure of delivery of a volatile anaesthetic. The authors concluded that an objective central nervous system depth of anaesthesia monitor and an improved drug administration system might have prevented the majority of these cases [132].

## Anaphylaxis

Life-threatening allergic reactions associated with anaesthesia occur in < 1:10 000 patients. Studies of anaphylaxis associated with anaesthesia show an incidence between 1:10 000 and 1:20 000 in Australia (1993) [133] and 1:13 000 in France (1996) [134]. A French survey of 467 patients with a history of anaphylaxis in 1997–98 revealed the main causal agents to be neuromuscular blocking drugs (69.2%), latex (12.1%) and antibiotics (8%). Clinical features included cardiovascular collapse (53.7%), cutaneous symptoms (69.6%), bronchospasm (44.2%), angio-oedema (11.7%) and cardiac arrest (4%) [135].

## Ocular complications

Peri-operative visual changes may vary in severity from transient diplopia or blurring of vision to irreversible blindness. A recent prospective study of 671 patients undergoing general anaesthesia or central neuraxial blockade reported the new onset of blurred vision lasting at least three days in 4.2% of patients, most of which resolved in one to two months. However, seven patients (1%) required eye care intervention for permanent blurred vision [136]. The incidence of ocular injury in

 

large prospective studies of nonocular surgery varies from 0.056% ($n = 60\,965$) [137] to 0.17% ($n = 4652$) [138]. The commonest injury sustained is corneal abrasion, in keeping with the findings of the ASA Closed Claims Analysis of ocular injury. They found 35% of all claims against anaesthesiologists for eye injuries were a result of corneal abrasions occurring during general anaesthesia [139].

Vision loss and blindness after surgery occur rarely, with a retrospective study of noncardiac surgery reporting an incidence of 1:125 234 ($n = 410\,189$) [140]. In cardiac surgical patients, the incidence increases, with 0.1–2% reporting loss of vision [141, 142].

### Deafness

Hearing loss may occur after general anaesthesia or spinal anaesthesia. Sudden sensorineural hearing loss (SNHL) has been extensively reported following cardiopulmonary bypass (incidence 1:1000 cases) presumably due to microemboli. In nonbypass cases, there are only 18 case reports in the literature of sudden SNHL following general anaesthesia in nonotological surgery. These are presumed to be due to cochlear or middle ear membrane breaks. Nitrous oxide has been implicated in this process because of pressure effects in the middle ear. The incidence of idiopathic sudden SNHL is 5–20:100 000 per year. However, there is a high rate of spontaneous recovery (47–78%) [143].

There have been reports in the literature of up to 16% of patients suffering transient hearing loss after spinal anaesthesia. It is hypothesised that the hearing loss is due to middle ear changes as a result of cerebrospinal fluid (CSF) leakage. Studies have shown a threefold increase in mild hearing loss in young patients (< 30 years) compared with their elders (> 60 years), suggesting that CSF leak after dural puncture occurs more frequently in younger patients [144, 145].

### Minor morbidity

Incidences of relatively minor morbidity, such as pain and postoperative nausea and vomiting, have not changed significantly over the last 30 years despite improvements in anaesthesia drugs and techniques [146, 147]. Minor sequelae following surgery often have a significant impact on patient recovery, leading to decreased function and slower resumption of daily activities after discharge [148, 149]. Much of the available data on minor sequelae are from studies in outpatients that attempt to identify areas for quality improvement [150].

### Postoperative pain

Inadequate management of acute pain in recent years has led to the development of multidisciplinary acute pain services in an attempt to improve quality of care [151–154]. The UK Audit Commission proposed in 1997 that < 20% of patients should experience severe pain following surgery after 1997, and that this should be decreased to < 5% by 2002 [155]. However, Dolin *et al*. [156] recently reviewed published studies on the incidence of moderate to severe pain after major surgery, and concluded that the overall incidence of moderate to severe pain was 30%, and that of severe pain was 11%. When looking at commonly used analgesic techniques, the incidence of moderate to severe and severe pain using intramuscular analgesia was 67 and 29%, respectively. For patient-controlled analgesia (PCA), the incidence of moderate to severe pain was 36% and severe pain 10%. In patients receiving epidural analgesia, the incidence of moderate to severe pain was 21% and severe pain 8%.

In ambulatory surgery, postoperative pain has been shown to be a major cause of delayed discharge, unplanned hospital admission and readmission [157]. A systematic review of postdischarge symptoms in outpatients reported an overall incidence of pain of 45% (range 6–95%) [150]. Severity of postoperative pain is dependent on both the type and length of surgical procedure. Of note, up to half the patients undergoing orthopaedic, laparoscopic and general surgical procedures still have significant pain at 24 h [158].

Patients' understanding of postoperative pain is poor. More than 50% of patients assume that pain is a normal part of the postoperative course and the healing process. Most are prepared to suffer pain rather than complain, and despite this > 80% are satisfied with their pain management [159]. The Australian National Health & Medical Research Council suggests that 'changes are called for in training, knowledge, attitudes and practice of medical, nursing and allied professionals along with greater public awareness and expectations in the treatment of pain' [154].

### Postoperative nausea and vomiting

Postoperative nausea and vomiting (PONV) is one of the most common and distressing complications following anaesthesia with an average reported incidence between 20 and 30% [160], but it may occur in up to 80% of patients [161]. In outpatients, the incidences of nausea and vomiting after discharge have been reported as 17 and 8%, respectively [150]. PONV has a multifactorial aetiology including type and duration of anaesthesia, drug therapy, type of surgery and patient characteristics. It is seen particularly in the young, females (three times the risk for males [162]), overweight, nonsmokers and in those with a history of motion sickness and previous PONV [40, 146, 160]. Surgical procedures such as laparoscopy, strabismus surgery, ear, nose and throat

(ENT), dental, orthopaedic and plastics operations have been associated with the highest incidence, suggesting operations that are associated with significant postoperative pain may lead to PONV [163–165]. Sinclair *et al.* [162] and Apfel et al. [166] have attempted to quantify the risks of PONV in individual patients by statistical analyses taking these factors into account.

The debate over optimal PONV management continues, in particular anti-emetic prophylaxis vs. symptomatic treatment. Looking at studies of efficacy and cost-effectiveness, Tramer *et al.* [166, 167] suggested that treatment of PONV with the $5HT_3$ antagonist ondansetron (1 or 4 mg) might be more cost-effective and safer than prophylaxis (4 or 8 mg). Other authors [169] now recommend routine anti-emetic prophylaxis in all patients at > 10% risk of PONV. Combination therapy, using a $5HT_3$ antagonist, dexamethasone and/or low-dose droperidol (0.625–1.25 mg), has been recommended if PONV risk exceeds 30% [169]. Rather than looking at a 'surrogate' outcome, such as percentage of patients vomiting, it has been suggested that true outcomes, such as patient satisfaction and delayed discharge, are more relevant [170].

### Sore throat

The incidence of sore throat following general anaesthesia has been studied prospectively in 5264 ambulatory patients, with a reported incidence of 12.1% overall at 24 h after surgery. The type of airway used affected the incidence, with 45% of patients complaining of sore throats after tracheal intubation, 18% after laryngeal mask (LMA) insertion and 3% following the use of a facemask [171]. Other studies quote a 14–64% incidence of sore throat in association with tracheal intubation, 9–29% with the LMA and 48% using a Combitube [172–177].

### Headache

The incidence of nonspecific headache after anaesthesia in outpatients is quoted as 17% (range 2–30%) [150]. Nikolajsen *et al.* [178] identified risk factors associated with postoperative headache, which included a daily caffeine consumption of > 400 mg in 24 h, pre-operative headache, those who normally experience two or more headaches per month, and a longer duration of fasting. They suggested caffeine withdrawal might cause symptoms within 12–16 h.

### Drowsiness and dizziness

Drowsiness has been reported as occurring after discharge in 42% (range 11–62%), and dizziness in 18% (range 7–41%) of outpatients [150]. A review by Holte *et al.* [179] concluded that intra-operative fluid administration of 1 l leads to a decrease in incidence of postoperative drowsiness and dizziness.

### Dental and oral damage

Oral tissue and dental damage are common complications of general anaesthesia and account for a significant proportion of all medicolegal claims against anaesthetists. A 10-year study of 598 904 procedures reported 132 cases (1:4500) of dental injury that required intervention. Nearly half of these injuries occurred during laryngoscopy and tracheal intubation [180]. A New Zealand survey of anaesthetists' practice estimated the incidence of dental damage to be 10.4:1000 [181]. Looking at all types of oral trauma, a prospective study of 404 patients having general anaesthetics with tracheal intubation showed an incidence of 6.9%, ranging from soft tissue laceration to tooth fracture or avulsion [182].

### Peripheral nerve injuries

Peripheral nerve injuries associated with anaesthesia are not uncommon. Dhuner's [184] retrospective review of > 30 000 cases over a 6-year period found nerve injuries in ∼ 1:1000 cases, most commonly involving the ulnar nerve (83%). More recently, prospective studies of postoperative ulnar neuropathy ($n = 1502$; $n = 6538$) revealed incidences of 1:200–1:350. Fifteen per cent of claims in the ASA Closed Claims Study followed perioperative nerve injury, in particular the ulnar nerve (> 30%), brachial plexus (23%) and lumbosacral nerves (16%) [183–187].

### Regional anaesthesia morbidity

Morbidity due to regional anaesthesia has been comprehensively reviewed [188]. Risks include neurological injury, death, cardiac arrest, local anaesthetic toxicity and infection. With central neuraxial blockade, which accounts for > 70% of regional anaesthesia practice, the risks of headache, backache and urinary dysfunction must also be considered.

In the 1950s, the incidence of permanent nerve injury following subarachnoid block was reported as 1:10 098 [189], and 2:10 000 after epidural anaesthesia (1969) [190]. More recently, Auroy *et al.*'s [74] prospective study of 103 730 regional anaesthetics found that long-term neurological injury was three times more common after subarachnoid block (1:10 000) than epidural block (0.3:10 000). In contrast, Dahlgren & Tornebrandt. [191] reported more long-term sequelae in their epidural group (10:10 000) than following spinals (3:10 000), with an overall incidence of 7:10 000 in 17 733 patients. The incidence of paraplegia in Auroy *et al.*'s study was 0.1:10 000 [74]. Transient neurological complications are more common. After subarachnoid blocks, the incidence varies between 4:10 000 (in 40 640 cases) [74] and 80:10 000 (10 098 cases) [189]. With epidurals, this varies between 1:10 000 and 10:10 000 [74, 190].

The incidence of spinal or epidural haematoma associated with central neuraxial blocks has been quoted as 1:150 000 for epidurals and 1:220 000 for spinals, from a study of 1.5 million patients [192]. The main risk factors are the presence of a coagulopathy, difficult insertion, presence of an epidural catheter and timing in relation to anticoagulant administration [193]. Regional differences have been noted in association with the dose of low molecular weight heparin (LMWH) used. In the USA, where a larger dose of LMWH tends to be used, the incidence of reported haematoma is 1:14 000 compared with 1:2 250 000 in Europe [194]. Interestingly, the risk of spontaneous spinal or epidural haematoma has been estimated as 1:1 000 000 [195].

In the obstetric population, demand for anaesthesia is increasing, with 22% of pregnant women undergoing Caesarean section in the UK [196]. Of these, > 90% of elective and 77% of emergency caesarean sections are performed under regional anaesthesia. Neurological deficits occurring after labour and delivery may be due to the obstetric process itself, secondary to regional analgesia or anaesthesia, or may occur spontaneously. Neurological complications after obstetric epidural analgesia or anaesthesia occur after 0.8–36.2:10 000 epidural blocks [197–202]. After spinal anaesthesia, these complications occur in 5.4–35.4:10 000 blocks [197, 202, 203]. There are no data from large-scale studies on neurological complications after combined spinal–epidural techniques. Cranial nerve palsies follow regional anaesthesia in 1–3.7:100 000 obstetric patients. The abducens nerve is most commonly affected, leading to diplopia [200, 204]. Looking at maternal obstetric palsies, the nerves most commonly injured include the lumbosacral plexus, femoral nerve, obturator nerve and common peroneal nerve. These occur due to nerve compression by the foetal head, during forceps delivery or due to patient positioning during labour. They occur more often after longer labours and high-risk deliveries and are mostly unilateral [197]. Ong *et al.* [201] reported maternal palsies in 18.9:10 000 deliveries ($n = 23\ 827$), manifested as paraesthesia and/or motor dysfunction, all of which resolved within 72 h with supportive care only. A common condition in pregnancy that may be wrongly attributed to regional analgesia or anaesthesia is *meralgia paresthetica*, resulting from compression of the lateral femoral cutaneous nerve (spinal roots $L_{2-3}$). Anterolateral thigh numbness or paraesthesia may occur from 30 weeks gestation but is self-limiting and usually resolves within three months of childbirth [197].

Transient radicular irritation has been described in association with spinal anaesthesia in the general population. It is characterised by mild to severe radiating back and buttock pain typically starting within 24 h, and lasting < 48 h. Risk factors include day surgery, lithotomy position and knee arthroscopy, and the incidence varies with the type of local anaesthetic used [205–207]; with 5% hyperbaric lignocaine, the incidence varies between 10 and 37%, with bupivacaine 0–3%, with mepivacaine 30–37% and with tetracaine 6.8% [188].

Auroy *et al.* [74] reported the mean (SD) incidence of cardiac arrest associated with spinal anaesthesia as 6.4 (1.2):10 000. In comparison, the incidence of cardiac arrest following epidural anaesthesia was much less at 1 (0.4):10 000. The risk of systemic local anaesthetic toxicity with epidural techniques is higher, with an incidence of 1:10 000, but there are no reported cases in subarachnoid blocks. Epidural abscesses and infection associated with central neuraxial blockade occur in between 1:1930 [208] and 1:7500 cases [209]. However, spontaneous epidural abscesses account for 0.2–2:10 000 hospital admissions per year [210]. The risk of infection is increased in the immunocompromised patient, patients on steroids and when epidural catheters are introduced. In the obstetric population, the incidence of epidural infection is reported between 0.2 and 3.7:100 000 following epidural anaesthesia [200, 204].

Post-dural puncture headache (PDPH) is one of the most common complications associated with spinal and epidural anaesthesia in inpatients, and the incidence is now quoted as $\sim$ 1% for both, although individual rates may vary widely (range: 0.6–4.2%) [188, 211]. The incidence of spinal headache can be decreased by the use of smaller gauge noncutting needle types [212]. Central neural blockade in outpatients has a reported 9% incidence of headache (range 1–37%) [150]. In obstetric practice, following the use of small gauge noncutting needles for spinal anaesthesia, the incidences of mild, moderate and severe headaches have been reported as 5.9, 4.7 and 0.75%, respectively [213]. Most authors quote an incidence of PDPH of 70–90% after inadvertent dural puncture with epidural needles, and an epidural blood patch success rate of 70–100%. Headache may recur in 30–50% [87, 214, 215]. Any persisting or recurring headaches must raise the suspicion of cranial subdural haematoma, which has an estimated incidence of 2:1 000 000 [200]. The incidence of accidental dural puncture in UK obstetric practice have been reported overall as 0.85% in 294 268 epidural insertions [216]. The fluid used for the loss of resistance technique may affect this rate, with dural puncture rates of 0.69% using saline and 1.11% using air. Long-term morbidity, such as headache and backache, after accidental dural puncture has also been reported [217, 218].

Prospective studies of postpartum back pain have found no association with epidural analgesia or anaesthesia, and

the incidence of backache two months after delivery has been reported as being the same regardless of anaesthetic technique used [219–221]. In fact, one of the most important factors associated with back pain following any surgery is the duration of the operation. Brown & Elman [222] reported an 18% incidence of back pain after surgery lasting $<1$ h, increasing to 50% with surgery lasting 4–5 h.

Urinary dysfunction is a common complication of neuraxial blocks with both opioids and local anaesthetics. Asantila *et al.* [223] compared different methods of postoperative analgesia after thoracotomy and reported a 90% incidence of urinary retention with epidural morphine 6 mg, and a 60% incidence with epidural bupivacaine 0.25%. Other authors have reported a 1–3% incidence of urinary dysfunction in patients receiving epidural infusions of bupivacaine and fentanyl [224]. In obstetric anaesthesia, studies of the effects of epidural analgesia on postpartum urinary retention have shown that although epidurals may be associated with an increase in residual urine in the bladder, postpartum urinary retention seems to be related more to prolonged or difficult labour than to the effects of epidural analgesia itself, with an incidence of up to 18% [225].

Systemic toxicity is another side effect of local anaesthetic use. This results most usually from inadvertent intravascular injection of the local anaesthetic. Auroy *et al.* [74] prospectively studied 21 278 regional anaesthetics that included 11 229 intravenous regional anaesthetics (IVRA). The risk of systemic toxicity to local anaesthetic overall was 1:10 000, with peripheral nerve blocks having the highest incidence of toxicity at 7.5:10 000. Seizures occurred in 2.7:10 000 intravenous regional anaesthetics [74]. The mean (SD) incidence of cardiac arrest was 1 (0.4):10 000 patients. Brown *et al.* [226] reported seizures during or after brachial plexus blocks in 20:10 000 patients. The incidence was lower in patients having an axillary block (12:10 000) compared with a supraclavicular block (79:10 000).

Auroy *et al.* [74] reported an incidence of permanent nerve injury after peripheral nerve block as 1.9:10 000, with all affected patients experiencing pain or paraesthesia during block insertion. Other authors report a 2% incidence of neurapraxia lasting up to three months following brachial plexus block [227]. Pneumothorax may also occur in association with supraclavicular brachial plexus blocks in up to 6.1% of patients [228, 229].

The use of local anaesthetic blocks for eye surgery is now common practice. The risk of retrobulbar haemorrhage after retrobulbar block has been reported as being between 0.5 and 44:10 000 [230, 231]. Brainstem anaesthesia occurs in $\sim$ 7–29:10 000 cases [232]. Globe perforation occurs in 1:12 000 cases [233], particularly in eyeballs with an axial length $>26$ mm. Transient complications, such as ptosis and diplopia, are also seen. The incidence of postoperative ptosis at 24 h after surgery is reported to be up to 50%, with residual problems in 20% of patients at one month [234]. Between 8 and 70% of patients suffer from diplopia at 24 h after surgery, with wide variations due to the different local anaesthetics used [235, 236].

## Discussion

Anaesthesia is generally perceived to be safe by the public, by surgeons and physicians, and by anaesthetists. This perception is, as we have shown, somewhat optimistic. Nevertheless, such a perception will exacerbate the anger of patients who suffer ill effects related to anaesthesia, particularly if the surgery for which anaesthesia is indicated is itself of marginal benefit or is only an optional or cosmetic procedure. Thus, if the surgery is judged by the anaesthetist to be of 'marginal' benefit or to be only of cosmetic benefit, the anaesthetist would be wise to be most diligent in explaining the attendant risks of anaesthesia, the reasons for particular techniques, and to allow the patient to become involved in the choices of anaesthetic management whenever possible.

Discussion with the patient of the risks of anaesthesia could potentially encourage anxiety about anaesthesia. Alfidi [237] showed that about a third of patients had increased anxiety after being given detailed information about angiography. However, a more recent Australian study on patient responses to detailed information about anaesthetic complications indicated that there was no increase in anxiety levels when detailed information was made available [238]. Thus, in the current medicolegal climate, patients should rarely have detailed information about the risks of anaesthesia or surgery withheld on the grounds that they are likely to suffer adversely from such information.

When detailing the specific risks of anaesthesia and surgery, patients should also be reminded of the risks they are subjected to in daily life in order to place these medical risks in perspective. Calman [239] has highlighted that the perceptions of any given risks are subjective, personality dependent, often subconscious and without any logical or rational basis. Both the patients' and the anaesthetists' perceptions will contribute to the discussion of risks. Anaesthetists should recognise that their own bias may influence the presentation of anaesthetic risks, and that 'informed consent' may suffer as a consequence.

The perception of risk is modified by a number of factors [240]:

*Probability of occurrence.* The true incidence requires a large population sample, and may be susceptible to regional bias in techniques, exposure bias (catastrophic or dramatic overpublicity) and compression/expansion bias (underestimates of large risks or overestimates of small risks). The specific objective of this review is to develop a list of the 'best guess' estimates of incidences for the important and common complications of anaesthesia based on the published literature. We have done this in Tables 7 and 8 with full realisation that there are many inadequacies in these illustrations, in which the numerators are dependent upon publication bias, medicolegal constraints and the reporting reticence inherent with medical complications. There are also often difficulties inherent in estimating the denominators. We hope that deficiencies and inaccuracies will be noted and improvements made that will more accurately reflect the true incidences of anaesthetic complications. In any event, these are global 'best guess' estimates, and each anaesthetist should substitute his or her own data for these global estimates wherever possible. Individual anaesthetists may have better or worse results for various anaesthetic complications depending on different levels of experience, frequency of use of various techniques, type of surgical and anaesthetic subspecialisation, patient population, etc.

*Severity.* High severity risks such as death, paraplegia and permanent organ failure, even though of very low probability, are perceived as higher overall risks than more common complications with a much greater incidence, such as PONV, sore throat or thrombophlebitis.

*Vulnerability.* Often denial or optimism and a feeling of immunity or invincibility allow us to go through life dismissive of the risks we take daily. Patients may feel more vulnerable because they are not in control, or, as is the situation with general anaesthesia, they are unconscious and thus have totally lost control of their circumstances. These concerns often magnify the importance of particular risks such as awareness.

*Controllability.* Loss of conscious choice, with a feeling of loss of control over events, increases the feeling of vulnerability and this is very pertinent to anaesthesia, particularly where general anaesthesia or heavy sedation is used. The issue of consent, together with a choice of clinical alternatives, is important, as patients who perceive that they have had adequate and realistic information, with the choice of different anaesthetic options, will be less resentful of any subsequent complications, just as smokers or motorcyclists accept the increased risks of their activities.

*Familiarity.* Patients who have had many major anaesthetic procedures before may be less worried about any inherent risks during future anaesthetics, even though those risks may increase with progression of disease processes and with ageing. Conversely, patients having their first anaesthetic experience may be more worried.

*Acceptability and dread.* Fear of paraplegia may feature more prominently with anaesthetists than stroke, major myocardial infarction or a patient's death. Cultural or regional expectations may alter these perceptions for both patients and anaesthetists. This particularly applies to the use of regional anaesthesia vs. general anaesthesia, where one or the other is dominant geographically, and hence the expected norm.

*Framing or presentation.* Particularly when relative risks are discussed with patients, positive framing [241] is better than negative framing. One may quote 90% survival rather than 10% mortality, or that outcomes are twice as good with one management regimen than with another, although the actual differences may only be between 0.005% and 0.01% mortality! However, such 'bias' should not impede discussion of the true incidence or real clinical significance with patients. Some anaesthetists may feel immune to complications that could occur in their practice either because of bravado or due to a misguided sense of the true incidence of a particular complication. Such anaesthetists may present too optimistic an opinion of the real risk to their patients. Unless anaesthetists have their own quality control figures to prove that their practice is better than the published data, we consider that they should use published data for risks of anaesthesia rather than anecdotal evidence. Where individual results are worse than published data, there may be good reasons, but it behoves the particular anaesthetist to be aware of this fact and to be honest with their patients, or be subject to the criticisms levelled at the Bristol Royal Infirmary paediatric cardiac surgeons [242].

Patients, particularly at times of anxiety related to surgery, will have great difficulty assimilating and retaining details such as incidences of complications. It is unlikely that detail will be assimilated or retained from a short visit the night before operation or just before the day of admission for surgery. Even a more leisurely preadmission consultation, remote in time from surgery, may be too detailed for full comprehension. Overload of information is sometimes used as an excuse for a very limited discussion of anaesthetic complications. Such an excuse is unlikely to satisfy an aggrieved patient or be used as defence against the legal challenge that follows. There would appear to be a place for a succinct leaflet given in advance to patients, listing the complications and placing them generally in perspective to everyday risks [243]. Such a leaflet may then be studied at leisure by the patient, who could then seek further clarification as necessary.

Presentation of relative everyday risks to patients may help to place the risks of potential anaesthetic complications in perspective. The logarithmic community cluster classification (Table 9) [244], which is based on Calman's

**Table 7** Predicted incidence of complications of anaesthesia.

| Mortality and morbidity | Incidence | Rate per 10 000 population | Remarks |
|---|---|---|---|
| Total peri-operative deaths (within 30 days) | ~ 1:200 (elective surgery) | 50 | |
| | ~ 1:40 (emergency surgery) | 250 | |
| | ~ × 2 (60–79 years) | | |
| | ~ ×5 (80–89 years) | | |
| | ~ ×7 (>90 years) | | |
| Death related to anaesthesia | ~ 1:50 000 (anaesthesia-related) | 0.2 | |
| | ~ 1:100 000 (ASA physical status I and II) | 0.1 | |
| Cardiac arrest | 1:10 000 – 1:20 000 (general anaesthesia) | 0.5–1.0 | Mortality ~ 1:15 000–1:150 000 |
| | ~ 1:3 000 (local anaesthesia) | 3 | |
| | ~ 1:1 500 (Spinal: 25% fatal) | 7 | |
| Myocardial re-infarction | ~ 1:20 (0-3 months after myocardial infarction | 500 | |
| | ~ 1:40 (4-6 months after myocardial infarction) | 250 | |
| Respiratory complications | | | |
| Aspiration during general anaesthesia | ~ 1:3 000 | 3 | ×4 in emergencies<br>×3 in obstetrics |
| | ~ 1:60 000 (Death) | 0.16 | |
| Difficult intubation | ~ 1:50 | 200 | |
| Failure to intubate | ~ 1:500 | 20 | Obstetrics ~ 1:250 |
| Failure to intubate & ventilate | ~ 1:5000 | 2 | |
| Postoperative cognitive dysfunction | ~ 1:4 at 1 week | 2500 | Regional anaesthesia |
| (> 60 years) | ~ 1:10 at 3 months | 1000 | ≈ General anaethesia |
| | ~ 1:100 permanent | 100 | |
| Postoperative delirium | ~ 1:7 (general surgery) | 1400 | × 3 >75 years |
| | up to ~ 1:2 for elderly fractures neck of femur | 5000 | ×3 if requiring intensive care |
| Drowsiness | ~ 1:2 | 5000 | Day surgery |
| Dizziness | ~ 1:5 | 2000 | Day surgery |
| Headache | ~ 1:5 | 2000 | |
| Cerebrovascular accident (CVA) | ~ 1:50 if previous stroke | 200 | 46% mortality |
| | ~ 1:100 general surgery | 100 | 60% mortality if previous CVA (~ 1:700 in the non-surgical population) |
| | ~ 1:20 head and neck surgery (~ 1:700 in the non-surgical population) | 500 | |
| Carotid endarterectomy (CVA + death) | ~ 1:15 if symptomatic | 700 | |
| | ~ 1:25 if asymptomatic | 400 | |
| (Disabling CVA + death) | ~ 1:50 | 200 | |
| Awareness | | | |
| with pain | ~ 1:3000 | 3 | 2/3 with neuromuscular blockade |
| without pain | ~ 1:300 | 30 | 1/3 without neuromuscular blockade |
| Total intravenous anaesthesia | ~ 1:500 | 20 | |
| Anaphylaxis | ~ 1:10 000 | 1 | |
| Deafness | | | |
| 'idiopathic' (general anaesthesia) | ~ 1:10 000 | 1 | ~ 1:1 000 cardiac surgery |
| transient after spinal anaesthesia | ~ 1:7 | 1500 | |
| Loss of vision | ~ 1:125 000 | 0.08 | |
| | ~ 1:100 (cardiac surgery) | 100 | |
| Pain | ~ 1:3 (moderate) | 3000 | |
| (after major surgery) | ~ 1:10 (severe) | 1000 | |
| (day surgery) | ~ 1:2 | 5000 | |
| Postoperative nausea and vomiting (PONV) | ~ 1:4 | 2500 | 2/3 nausea and 1/3 vomiting<br>Female:male 3:1 |
| Sore throat | ~ 1:2 (if tracheal tube) | 5000 | |
| | ~ 1:5 (if laryngeal mask) | 2000 | |
| | ~ 1:10 (if facemask only) | 1000 | |
| Dental damage | | | |
| requiring intervention | ~ 1:5000 | 2 | |
| all dental damage | ~ 1:100 | 100 | |
| all oral trauma after tracheal intubation | ~ 1:20 | 500 | |

**Table 7** (Continued).

| Mortality and morbidity | Incidence | Rate per 10 000 population | Remarks |
|---|---|---|---|
| Peripheral nerve injury | ~ 1:300 ulnar neuropathy | 30 | |
| (general anaesthesia) | ~ 1:1 000 (other nerves) | 10 | |
| Thrombophlebitis | ~ 1–2:20 water-soluble drugs | 500–1000 | |
| | ~ 1:4 propylene glycol-based | 2500 | |
| Arterial cannulation complications | < 1:100 (permanent) | <100 | |
| Pulmonary artery perforation | ~ 1:2000 | 5 | |
| Arterial Puncture (during central venous cannulation) | | | |
| internal jugular vein cannulation | ~ 1:35 | 350 | |
| subclavian vein cannulation | ~ 1:200 | 50 | |

**Table 8** Predicted incidence of complications of regional anaesthesia.

| | Incidence | Rate per 10 000 population | Remarks |
|---|---|---|---|
| Paraplegia | ~ 1:100 000 | 0.1 | |
| Permanent Nerve Injury | | | |
| spinal | 1–3:10 000 | 1–3 | |
| epidural | 0.3–10:10 000 | 0.3–10 | |
| peripheral nerve block | ~ 1:5000 | 2 | 2% brachial plexus neuropraxia lasting >3 months |
| Epidural haematoma | ~ 1:150 000 (epidural) | 0.07 | ~ 1:1 000 000 (spontaneous) |
| | ~ 1:200 000 (spinal) | 0.05 | ~ 1:14 000 (USA)<br>~ 1:2 250 000 (Europe)<br>~ 1:10 000 (spontaneous) |
| Epidural abscess | 1:2000–1:7500 | 0.7–5.0 | |
| Transient neural complications | 1:1000–1:10 000 (epidural) | 1–10 (epidural) | |
| | 1:125–1:2 500 (spinal) | 4–80 (spinal) | |
| Transient radicular irritation (spinal) | Up to 1:3 (heavy lidocaine and mepivacaine) | 3000 | |
| Cardiac arrest | ~ 1:1500 (spinal) | 5 (spinal) | |
| | ~ 1:3000 (local anaesthesia) | 3 (local anaesthesia) | |
| | ~ 1:10 000 (epidural) | 1 (epidural) | |
| | ~ 1:10 000 (regional blocks) | 1 (regional) | |
| Post-dural puncture headache | ~ 1:100 | 100 | 80% following inadvertent dural tap |
| | ~ 1:10 (day surgery) | 1000 | Blood patch 70–100% Immediate success but headaches recur in 30–50% |
| Backache | < 1 h surgery ~ 20% | 2000 | GA ≈ LA |
| | > 4 h surgery ~ 50% | 5000 | |
| Urinary dysfunction | ~ 1:50 | 200 | |
| Pneumothorax | ~ 1:20 (supraclavicular blocks) | 500 | |
| Systemic LA toxicity | ~ 1:10 000 (epidural) | 1 | |
| | ~ 1:1500 (regional blocks) | 7 | |
| Cerebral seizures | ~ 1:4000 (intravenous regional anaesthesia) | 2.5 | Axillary ~ 1:1000 |
| | ~ 1:500 (brachial plexus) | 20 | Supraclavicular ~ 1:125 |
| Eye blocks | | | |
| Retrobulbar haemorrhage | 1: 250–1:20 000 | 0.5–40 | |
| Brainstem anaesthesia | ~ 1:700 | 15 | |
| Globe perforation | ~ 1:10 000 | 1 | |
| Ptosis – transient after eye block | ~ 1:2 at 24 h | 5000 | |
| | ~ 1:5 at 1 month | 2000 | |
| Diplopia – transient after eye block | 8–70% | 800–7000 | |

verbal scale [239], is one way to describe the relative risks that may also be presented graphically [245].

Another comparison is with the lottery probability scale [246], but this seems unnecessarily complex and has the wrong emphasis, as gamblers are invariably too optimistic and patients are usually too pessimistic.

Whilst we have focused on the risks of anaesthesia, there are other aspects as indicated by Paul de Gondi's

**Table 9** Community cluster logarithmic scale of risk classification (modified from Calman & Roystone [244] and Admas & Smith [247]).

| Risk level | Calman's Verbal Scale | Community | Community examples | Anaesthetic or medical examples |
|---|---|---|---|---|
| 1:1–9 | Very High | Sibling | Genetic dominant | Postoperative nausea and vomiting 1:4<br>Dizziness 1:5<br>Headache 1:5 |
| 1:10–99 | High | Family | Genetic recessive | All oral trauma following intubation 1:20<br>Emergency surgery death 1:40<br>Difficult intubation 1:50 |
| 1: 100–999 | Moderate | Street | Deaths per year 1: 100 | Peri-operative death 1:200<br>Awareness without pain 1:300<br>Failure to intubate 1:500 |
| 1: 1000–9999 | Low | Village | Traffic deaths per year 1:8000 | Awareness with pain 1:3000<br>Aspiration 1: 3000<br>Cardiac arrest 1:3000 (local anaesthesia)<br>Epidural abscess ~1:5000 (local anaesthesia)<br>Failure to intubate and ventilate 1:5000 |
| 1:10 000–99 999 | Very Low | Small Town | Accidental deaths at home per year 1:11 000 | Anaphylaxis 1:10 000<br>Spontaneous epidural abscess 1:10 000<br>Cardiac arrest ~1:15 000 (general anaesthesia)<br>Death (related to anaesthesia) 1:50 000 |
| 1:100 000–999 999 | Minimal | Large Town | Rail accidents per year 1:140 000 | Loss of vision (general anaesthesia) 1:125 000<br>Paraplegia (local anaesthesia) 1:100 000<br>Epidural haematoma 1:150 000–1:200 000<br>Death due solely to anaesthesia 1:180 000 |
| 1:1 000 000–9 999 999 | Negligible | City | Six balls in UK National Lottery 1:2 796 763 | Spontaneous epidural haematoma 1:1 000 000 |
| 1:10 000 000–99 999 999 | Minute | Country | Lightning deaths per year 1:10 000 000 | |

quotation at the beginning of this article. The benefits of different management options (medical, surgical and anaesthetic) also have varying probabilities and 'spin' which we have not attempted to address here. The mnemonic *BRAN* offers a useful approach when assessing the risks of a course of action, and includes the **B**enefits, **R**isks, **A**lternatives and what would happen if **N**othing were done [240]. We believe we have made a start by establishing a listing of the incidences of various anaesthetic complications. Much work remains to be done to establish incidences of the inherent benefits in different clinical situations, and also for alternatives including the option of doing nothing. We have no doubt that better and more complete listings of incidences of anaesthetic complications will be developed. This is but a start.

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