Anaesthesia 2014, 69, 1299–1313

Editorial

Quantifying and communicating peri-operative risk

Shallow men believe in luck. Strong men believe in cause and effect

—Ralph Waldo Emerson

Life is risky

Risk is the potential that a chosen action or activity (including the choice of inaction) will lead to a specific outcome, and implies that the choice has an influence on the outcome. Most definitions are synonymous with the possibility of an adverse event but, of course, a risk can also be taken in the hope of a favourable outcome, particularly with investment. There is also a personal perspective on risk. A fatalist personality may be very accepting and unconcerned about risk whereas more pragmatic individuals know that there can be modifiable factors involved. This can apply to healthcare; for example, even though surgery may be necessary in a patient, there may be pharmaceutical interventions that could reduce morbidity. Almost any human endeavour carries some risk. Staying in hospital is far riskier than travelling by aeroplane. A recent study showed that a one-night stay in hospital carries a 11.1% risk of nosocomial infection, a 3.4% risk of an adverse drug reaction related to human error or allergy, and a 0.4% risk of pressure ulcer due to immobilisation [1]. In 2007 in the USA, there were 1.31 fatal crashes per 100 000 flight hours for non-commercial flights and 0.016 per 100 000 for major airlines [2]. Despite efforts to the contrary, healthcare is an intrinsically hazardous business.

Anaesthesia is a medical specialty very much focused on risk management and patient safety and, consequently, the mortality risk attributable to anaesthesia itself has dropped dramatically over the years, from about one death in 1000 anaesthetic procedures in the 1940s to one in 100 000 in the early 2000s [3]. However, although anaesthesia is relatively safe, surgery can be very dangerous. In 2000, the 30-day mortality risk in the UK was one death in 34 emergency operations (2.9%) and 1:177 after elective surgery (0.6%) [4]. The European Surgical Outcomes Study was an observational study in which data were collected on 46 539 patients aged ≥ 16 years undergoing non-cardiac surgery, over a seven-day period, in 498 hospitals across 28 European nations [5]. There was considerable variability from country to country but median death rates were 3% for elective and 10% for emergency surgery. Anaesthesia has an excellent track record for patient safety and has been described as the leading medical specialty in addressing such issues [6], yet it is apparent that the peri-operative process still has great potential for hazard from a host of factors, of which anaesthesia is but one.

Ronald A. Howard, a pioneer of decision analysis, wanted to develop a scale that would more clearly confer risk rather than percentages. He coined the term 'microprobability' to refer to an event with a chance of one in a million. From this concept, a 'micromort' (from 'micro' and 'mortality') is then a one in a million chance of death [7]. We face risk simply by being alive and this may be exacerbated by indulging in various activities. A mobile app is now available for illustrating how many micromorts are involved in our daily activities (see https://play.google.com/store/apps/details?id=com.zanzibartech.micromorts). The use of micromorts then allows us actually to quantify risk and translate it into whole numbers. A micromort denotes a one in a million chance of death from one-time dangerous events, a concept that can be easily understood and compared. A one in a million chance is, of course, rare but also an everyday occurrence. For example, the chance of a particular individual's winning the weekly lottery is less than 1 in 32 million

people, but conversely this jackpot gets won almost every week by somebody. Micromorts are an expression of acute risks, such that once that event has been completed the risk has gone. The risk of surgical anaesthesia is in the range of various day-to-day activities. Audits of the risk of death from a general anaesthetic alone vary considerably geographically, but may be around one death in 100 000 operations in a developed country [8], which equates to 10 micromorts per operation. This is the same risk of death, on average, as riding a motorcycle for 60 miles or skydiving. Micromorts rely on aggregated risk data for calculations, so their applicability to specific circumstances or individuals is limited. In contrast with micromorts, there is also a unit called microlife which is a risk (or gain) representing a 30-minute change of life expectancy [9]. It is a way of measuring the impact of long-term habits on the human body. For example, smoking two cigarettes will 'cost' one microlife; whereas bonus life can be gained by taking a statin daily (one microlife per day) or doing 20 minutes of moderate exercise daily (two microlives per day). A user-friendly microlife calculator (see http://journals.bmj.com/site/microlives) is available. People in general are notoriously bad at calculating risk. The concept of micromort and microlife can be useful for explaining various risks in our daily peri-operative practice to the general public.

The blind leading the blind?

Shared decision-making in the healthcare context very often depends on the understanding of numerical information, in either text or graphical format. The perception of harm and benefit associated with particular options is important for many health decisions. Surprisingly, not only patients but many doctors have severe problems mastering a host of numerical concepts that are prerequisites for understanding information about the harm and benefit of medical treatments [10]. Highly educated people can still have difficulty with relatively simple numeracy questions [11]. Numeracy influences the processing of both numerical and non-numerical information. Less numerate individuals are more susceptible to framing effects, more easily affected by non-numerical information such as mood states, and less sensitive to different levels of numerical risk [12]. The Berlin Numeracy Test is a new psychometric instrument for assessing statistical numeracy and risk literacy in an educated population [13]. It typically takes three minutes to complete and an online version is now also available (see http://www.risklit-eracy.org).

Statisticians, clinicians and psychologists have recommended the use of numerical as opposed to verbal descriptions for risk communication [14–16]. In addition to probability information, the way people perceive a risk message may be influenced by the framing of risk information, risk comparisons, the message's qualitative content and trust [17]. Conveying relative risks alone without absolute risk or baseline risk is an example of non-transparent framing. Comparing benefits and harm using different scales, such as reporting benefits in big numbers by relative risk reduction and harm in small numbers by absolute risk increases, is another way of altering risk perception. An example is the 1995 contraceptive pill scare in the UK, where an alarming figure of a 100% increase (relative) in thrombosis caused by third-generation oral contraceptive pills was much more terrifying than a humble increment in absolute risk, from one in 7000 to two in 7000 [18]. Humans can be prone to unwittingly tricking themselves with representative bias in risk assessment in gambling pursuits such as purchasing lottery tickets. If the odds of winning a lottery are one in a million, then buying two tickets will 'double' the chance to two in a million (an apparent 100% increase). However, the odds of *not* winning the jackpot by buying two lottery tickets hardly changes at all (from 99.9999% to 99.9998%; a change of 0.0001%).

Non-transparent and mismatched framings are common phenomena, even for scientific research published in leading medical journals. Studies have revealed that up to half of articles report only relative risks or odds ratios, and about one third adopt mismatched framing for risk-benefit discussion [19, 20]. Risk communication with incomplete and misleading numerical descriptions hinders shared decision-making. Patients are likely to be familiar with the concept of risk, but human nature is such that many do not understand the relativity or perhaps even choose to ignore it. To use gambling again as an example, a recent $640 million lottery in the USA created much excitement and

a scramble to buy tickets when the odds of winning were approximately one in 175 million. That number may not mean much in itself, but in relative terms the chance of winning is 175 times less than that of being struck by lightning in a given year, a fact that helps conceptualise probability.

As in life, there is no zero risk and no certainty in any branch of medicine, but only risks that are more or less acceptable. Communicating risk information is important but, unfortunately, more difficult than might be expected. Patients' values and preference are essential elements of shared decision-making. In 2011, a report on the peri-operative care of surgical patients published by the National Confidential Enquiry into Patient Outcome and Death principally recommended that "*an assessment of mortality risk should be made explicit to the patient and recorded clearly on the consent form and in the medical record*" [21]. A spreadsheet has been developed to quantify mortality risk before and after surgery by calculating mortality rates, and life expectancy with adjustment for various parameters such as age, sex, co-morbidities, renal function, physical fitness, and body mass index [22]. An on-line calculator is available for estimating peri-operative mortality in order to assist shared decision-making between patients and their doctors when non-surgical intervention is an option (see https://sites.google.com/site/informrisk/).

The complex nature of the peri-operative period gives rise to the potential for significant risk to all patients. Directing efforts towards patient safety can be uncomplicated and inexpensive, yet significantly improve the quality of peri-operative care. The World Health Organization's surgical safety checklist is an example of a simple, cheap and effective method of reducing avoidable complications resulting from surgery [23]. Moreover, the use of a checklist is likely to provide a net financial benefit to the healthcare system because the cost of the intervention is low under all scenarios and there should be a reduction in morbidity and medicolegal claims. Anaesthesia is a medical discipline of applied science related to the art of peri-operative risk reduction by identification, intervention, and prevention.

To test or not to test

High-risk patients account for no more than 15% of all surgical procedures but over 80% of deaths [24]. However, it is still a major challenge to identify accurately and reliably patients who are at high risk of postoperative mortality and morbidity. Cardiopulmonary exercise testing (CPET) is a measure of aerobic capacity that is becoming more widely employed, with the estimated number of tests performed in the UK alone estimated to be in excess of 14 000 per year [25]. Based on the possible association of pre-operative aerobic fitness with subsequent survival after surgery, CPET has been used for triaging patients with occult cardiorespiratory disease for further investigation and optimisation strategies before major operations [26]. Nonetheless, none of the derived variables, such as ventilatory anaerobic threshold or maximal oxygen uptake, can be regarded as a cornerstone for the prediction of survival after major surgery [27]. The European Society of Cardiology's guidelines on pre-operative cardiac risk assessment and peri-operative cardiac management, published in 2009, questioned the role of CPET in risk assessment before surgery and emphasised that it is not a substitute for stress testing in routine practice [28]. A scientific statement from the American Heart Association has also highlighted the lack of randomised trials to support recommendations for diagnostic and prognostic applications of CPET [29]. Reliance upon any single factor in predicting future risk is more like gambling than rational assessment, since no test is infallible. No single variable can estimate the extent of survival and quality of life, although physical fitness appears to be an important component [30, 31]. Pre-operative testing should not be a screening exercise for stable patients but a strategic part of the peri-operative risk reduction programme for susceptible patients. Risk assessment should always be tailored to individual patients, and pre-operative tests only reserved for those in whom test results would positively influence and change peri-operative management. Our drive to 'optimise risk' can lead to unnecessary investigation and intervention when we should really be optimising 'risk assessment' through more comprehensive history taking and physical examination. Concerns over malpractice liability result in excessive and unnecessary consulta-

tion, hospitalisation, testing, and treatment can, paradoxically, be a safety hazard for both patients and doctors, with false positive findings leading to costly and possibly harmful treatments or further investigations and delays in surgery. The quantity of tests should not be confused with the quality of care.

Are drugs the answer?

Is there a pharmacological panacea for peri-operative risk optimisation? One of the main objectives of risk identification is to determine which individuals could benefit from a protective, therapeutic intervention. If that intervention is potentially dangerous in itself, e.g. coronary artery stenting, then careful selection is absolutely essential. There are, however, fairly safe and simple pharmacological treatments that are very promising in this regard. It may not be necessary to investigate patients aggressively with expensive and even hazardous techniques if the indication for surgery is very strong. Why not assume the worst and instigate protective measures anyway? Over the last decade, statins have been investigated extensively for their potential multimodal effects in modifying a number of aspects of peri-operative morbidity and mortality [32–34]. Possible pleiotropic effects of statin therapy are reduction of myocardial infarction and stroke, prevention of atrial fibrillation, improvement of vascular draft survival, protection from renal insufficiency, and inhibition of malignant cell growth [34]. All peri-operative applications of statins are 'off-label', as their primary indication is lipid-lowering, but the drugs, which are now available in generic form, are relatively inexpensive with a very good safety profile [35]. However, in the latest Cochrane review of statins for vascular surgery, there was insufficient evidence to conclude that use of statins resulted in either a reduction or an increase in any of the outcomes examined. It was also observed that the widespread use of statins in the population now will make it difficult for researchers to undertake the large randomised trials needed to demonstrate any effect [36].

Peri-operative pharmacological interventions, while having certain benefits, may themselves be associated with risk that could outweigh such advantages. Data from the POISE trial suggested that routine administration of peri-operative beta-blockers in an un-titrated, relatively high dose starting on the day of operation, increased the risk of stroke and overall mortality for non-cardiac surgery in the presence of favourable outcomes on other cardiovascular parameters [37, 38]. POISE II has generated similar controversy recently over the use of peri-operative aspirin [39].

Conclusions

Anaesthesia, as a service-based speciality dealing with specific incident-related risks, has not yet reached its peak despite being acknowledged as the leading medical speciality in designing fail-secure systems and probably the only specialty in healthcare to have reached the critical target of six sigma defect rate [6, 40]. The peri-operative period could be made safer by revolutionising risk management tactics with corresponding interventions in preventing complications and improving patient outcomes. It has been suggested that the technical aspects of anaesthesia could be delegated to robots [41], so are we ready for our new role as peri-operative risk strategists?

Competing interests

No external funding and no competing interests declared.

M. G. Irwin
Professor
V. K. F. Kong
Honorary Assistant Professor
Department of Anaesthesiology
University of Hong Kong,
Hong Kong
Email: mgirwin@hku.hk

References

1. Hauck K, Zhao X. How dangerous is a day in hospital? a model of adverse events and length of stay for medical inpatients. *Medical Care* 2011; **49**: 1068–75.
2. Li G, Baker SP. CRash risk in general aviation. *Journal of the American Medical Association* 2007; **297**: 1596–8.
3. Li G, Warner M, Lang BH, Huang L, Sun LS. Epidemiology of anesthesia-related mortality in the United States, 1999–2005. *Anesthesiology* 2009; **110**: 759–65.
4. Jenkins K, Baker AB. Consent and anaesthetic risk. *Anaesthesia* 2003; **58**: 962–84.
5. Pearse RM, Moreno RP, Bauer P, et al. Mortality after surgery in Europe: a 7 day cohort study. *Lancet* 2012; **380**: 1059–65.
6. Leape LL. Error in medicine. *Journal of the American Medical Association* 1994; **272**: 1851–7.
7. Howard RA. Microrisks for medical decision analysis. *International Journal of Technology Assessment in Health Care* 1989; **5**: 357–70.
8. Aitkenhead AR. Injuries associated with anaesthesia. A global perspective. *British Journal of Anaesthesia* 2005; **95**: 95–109.

9. Spiegelhalter D. Using speed of ageing and microlives to communicate the effects of lifetime habits and environment. *British Medical Journal* 2012; **345**: e8223.
10. Galesic M, Garcia-Retamero R. Using analogies to communicate information about health risks. *Applied Cognitive Psychology* 2013; **27**: 33–42.
11. Lipkus IM, Samsa G, Rimer BK. General performance on a numeracy scale among highly educated samples. *Medical Decision Making* 2001; **21**: 37–44.
12. Peters E. Beyond comprehension: the role of numeracy in judgments and decisions. *Current Directions in Psychological Science* 2012; **21**: 31–5.
13. Cokely ET, Galesic M, Schulz E, Ghazal S, Garcia-Retamero R. Measuring risk literacy: the Berlin numeracy test. *Judgment and Decision Making* 2012; **7**: 25–47.
14. Smith A. Foreword to the papers on 'The communication of risk'. *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 2003; **166**: 205–6.
15. Edwards A. Communicating risks. *British Journal of Anaesthesia* 2003; **327**: 691–2.
16. Gigerenzer G, Gaissmaier W, Kurz-Milcke E, Schwartz LM, Woloshin S. Helping doctors and patients make sense of health statistics. *Psychological Science in the Public Interest* 2007; **8**: 53–96.
17. Visschers VHM, Meertens RM, Passchier WWF, De Vries NNK. Probability information in risk communication: a review of the research literature. *Risk Analysis* 2009; **29**: 267–87.
18. Furedi A. The public health implications of the 1995 'pill scare'. *Human Reproduction Update* 1999; **5**: 621–6.
19. Schwartz LM, Woloshin S, Dvorin EL, Welch HG. Ratio measures in leading medical journals: structured review of accessibility of underlying absolute risks. *British Medical Journal* 2006; **333**: 1248.
20. Sedrakyan A, Shih C. Improving depiction of benefits and harms: analyses of studies of well-known therapeutics and review of high-impact medical journals. *Medical Care* 2007; **45**: S23–S8.
21. Findley G, Goodwin A, Protopapa K, Smith N, Mason M. *Knowing the risk: a review of the peri-operative care of surgical patients*. London: NCEPOD, 2011.
22. Carlisle JB. Pre-operative co-morbidity and postoperative survival in the elderly: beyond one lunar orbit. *Anaesthesia* 2014; **69**: 17–25.
23. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *New England Journal of Medicine* 2009; **360**: 491–9.
24. Pearse R, Harrison D, James P, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Critical Care* 2006; **10**: R81.
25. Huddart S, Young EL, Smith R-L, Holt PJ, Prabhu PK. Preoperative cardiopulmonary exercise testing in England–a national survey. *Perioperative Medicine* 2013; **2**: 4.
26. Kothmann E, Danjoux G, Owen SJ, Parry A, Turley AJ, Batterham AM. Reliability of the anaerobic threshold in cardiopulmonary exercise testing of patients with abdominal aortic aneurysms. *Anaesthesia* 2009; **64**: 9–13.
27. Colson M, Baglin J, Bolsin S, Grocott MPW. Cardiopulmonary exercise testing predicts 5 yr survival after major surgery. *British Journal of Anaesthesia* 2012; **109**: 735–41.
28. Poldermans D, Bax JJ, Boersma E, et al. Guidelines for pre-operative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery: The Task Force for Preoperative Cardiac Risk Assessment and Perioperative Cardiac Management in Non-cardiac Surgery of the European Society of Cardiology (ESC) and endorsed by the European Society of Anaesthesiology (ESA). *European Heart Journal* 2009; **30**: 2769–812.
29. Balady GJ, Arena R, Sietsema K, et al. Clinician's guide to cardiopulmonary exercise testing in adults: a scientific statement from the American Heart Association. *Circulation* 2010; **122**: 191–225.
30. Carlisle JB. The quick and the dead. *Anaesthesia* 2013; **68**: 799–803.
31. Lee L, Schwartzman K, Carli F, et al. The association of the distance walked in 6 min with pre-operative peak oxygen consumption and complications 1 month after colorectal resection. *Anaesthesia* 2013; **68**: 811–6.
32. Biccard BM. A peri-operative statin update for non-cardiac surgery. Part II: Statin therapy for vascular surgery and peri-operative statin trial design. *Anaesthesia* 2008; **63**: 162–71.
33. Biccard BM. A peri-operative statin update for non-cardiac surgery. Part I: The effects of statin therapy on atherosclerotic disease and lessons learnt from statin therapy in medical (non-surgical) patients. *Anaesthesia* 2008; **63**: 52–64.
34. Chan WW, Wong GT, Irwin MG. Perioperative statin therapy. *Expert Opinion on Pharmacotherapy* 2013; **14**: 831–42.
35. Minder CM, Blumenthal RS, Blaha MJ. Statins for primary prevention of cardiovascular disease: the benefits outweigh the risks. *Current Opinion in Cardiology* 2013; **28**: 554–60.
36. Sanders RD, Nicholson A, Lewis SR, Smith AF, Alderson P. Perioperative statin therapy for improving outcomes during and after noncardiac vascular surgery. *Cochrane Database of Systematic Reviews* 2013; **7**: CD009971.
37. Devereaux P, Yang H, Yusuf S, et al. Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery (POISE trial): a randomised controlled trial. *Lancet* 2008; **371**: 1839–47.
38. Wijeysundera DN, Duncan D, Nkonde-Price C, et al. Perioperative beta blockade in noncardiac surgery: a systematic review for the 2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Journal of the American College of Cardiology* 2014 Aug 1; doi 10.1016/j.jacc.2014.07.939.
39. Devereaux PJ, Mrkobrada M, Sessler DI, et al. Aspirin in patients undergoing noncardiac surgery. *New England Journal of Medicine* 2014; **370**: 1494–503.
40. Amalberti R, Auroy Y, Berwick D, Barach P. Five system barriers to achieving ultrasafe health care. *Annals of Internal Medicine* 2005; **142**: 756–64.
41. Hemmerling TM, Terrasini N. Robotic anesthesia: not the realm of science fiction any more. *Current Opinion in Anesthesiology* 2012; **25**: 736–42.

doi:10.1111/anae.12881

