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Perioperative Mortality Rate (POMR): A Global Indicator of Access to Safe Surgery and Anaesthesia

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Abstract

Introduction The unmet global burden of surgical disease is substantial. Currently, two billion people do not have access to emergency and essential surgical care. This results in unnecessary deaths from injury, infection, complications of pregnancy, and abdominal emergencies. Inadequately treated surgical disease results in disability, and many children suffer deformity without corrective surgery.

Methods A consensus meeting was held between representatives of Surgical and Anaesthetic Colleges and Societies to obtain agreement about which indicators were the most appropriate and credible. The literature and state of national reporting of perioperative mortality rates was reviewed by the authors.

Results There is a need for a credible national and/or regional indicator that is relevant to emergency and essential surgical care. We recommend introducing the perioperative mortality rate (POMR) as an indicator of access to and safety of surgery and anaesthesia. POMR should be measured at two time periods: death on the day of surgery and death before discharge from hospital or within 30 days of the procedure, whichever is sooner. The rate should be expressed as the number of deaths (numerator) over the number of procedures (denominator). The option of before-discharge or 30 days is practical for those low- to middle-income countries where postdischarge follow-up is likely to be incomplete, but it allows those that currently can report 30-day mortality rates to continue to do so. Clinical interpretation of POMR at a hospital or health service level will be facilitated by risk stratification

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using age, urgency (elective and emergency), procedure/procedure group, and the American Society of Anesthesiologists grade.

Conclusions POMR should be reported as a health indicator by all countries and regions of the world. POMR reporting is feasible, credible, achieves a consensus of acceptance for reporting at national level. Hospital and Service level POMR requires interpretation using simple measures of risk adjustment such as urgency, age, the condition being treated or the procedure being performed and ASA status.

Introduction

A significant proportion of the global burden of surgical disease is treatable [1–3]. Someone in need of emergency or essential surgery has no therapeutic alternative to a surgical procedure. Thus, adequate primary health care for such patients demands a triage and referral system that leads to a timely operation and, with it, the safe administration of anaesthesia. Such a system will result in fewer deaths and a better chance of living without deformity or disability.

In many low- and middle-income countries (LMICs), the infrastructure, facilities, and expertise are inadequate to deliver needed essential or emergency surgical procedures and safe anaesthesia. Only 8.1 million (3.5 %) of the world's 230 million surgical procedures performed annually take place in LMICs [4], whilst it is estimated that 2 billion of the world's 7 billion people do not have access to safe surgery and anaesthesia. Each year this results in an estimated 60,000 unnecessary maternal deaths (25 % of 250,000 per annum) [1]. There are 2 million potentially avoidable deaths amongst the 5 million annual deaths due to injury [5], and many more among the growing burden of noncommunicable diseases such as cardiovascular disease, diabetes, and cancer, some of which can be ameliorated by surgery [1–3, 6]. If the anaesthesia-associated mortality rate is about 1:500 in developing countries [7], and half of the deaths were avoidable, we estimate each year there are 35,000 avoidable anaesthetic deaths among the 35 million operations in LMICs.

In the last two decades (1995–2014) the Millennium Development Goals (MDG) defined the key global strategies, including health interventions, that impacted economic well-being. While the MDGs were based on an appreciation of health needs of the early 1990s, the exclusive commitment to these goals in many LMICs resulted in scant attention to the diagnosis and treatment of surgical disease. Surgery and anaesthesia were only broadly and inferentially included under MDG 6, which contained the goal of treating “other diseases.” Even the provision of emergency surgery was largely neglected, and

nowhere is this more obvious than for MDG 5, which addressed maternal health, including the widely accepted metric of maternal mortality rates (MMR). Despite considerable improvements in MMR as a result of recommendations for prenatal assessment and the presence of a skilled birth attendant, further significant reductions in maternal mortality will be limited without addressing access to and safety of surgery and anaesthesia for the 15 % of pregnancies that require a procedure to manage the complications of preeclampsia, obstructed labour, or haemorrhage. In the absence of safe surgery and anaesthesia, entire communities bear the burden of disability, deformity, and death from pregnancy.

Strengthening surgical care in LMICs requires both improving access to surgical and anaesthetic services and improving the safety of those services. Little is known about surgical and anaesthetic outcomes in LMICs as these are not formally reported [8, 9]. As the United Nations [10], World Health Organization (WHO), and Ministries of Health prepare to define post-2015 global health priorities under the umbrella of universal health coverage, specific goals for access to and safety of surgery and anaesthesia are needed. In this article we describe how a key indicator of safety—the perioperative mortality rate (POMR)—may be used to improve the quality of care received by patients everywhere, and especially in resource-poor settings.

The perioperative mortality rate (POMR)

Global health metrics are usually summarized using health indices. Some, such as life expectancy and infant and MMR, are often used as proxy measures for overall health status. These indices enable comparisons of the causes of ill health and benchmarking of the impact of health interventions. Health indicators provide data for evaluation of population health at all levels—local, national, regional, and global.

Surgical disease affects both genders and all decades of life. Therefore, a health index applicable to surgery has been challenging to define, even more so because surgery covers a diverse range of conditions and diseases. However, a “surgical” health index is necessary for the evaluation and ultimate improvement of surgical and anaesthetic interventions directed at the burden of surgical disease. The POMR has been proposed by several independent groups interested in surgical and anaesthesia outcomes [7, 11, 12], and we advocate that the POMR should be recognized as a health indicator of the quality and safety of surgery and anaesthesia.

The POMR is defined as death following surgery and anaesthesia within two time periods: on the day of surgery (including death in the operating theatre) and before

Table 1 Measuring perioperative mortality rates

	Definition	Rationale for use	Data sources	Comments
Number of surgical procedures done in an operating room per year	The absolute number of all surgical procedures, defined as the incision, excision, or manipulation of tissue that requires regional or general anaesthesia or profound sedation to control pain, undertaken in an operating room	Surgical volume is an indication of the access to and use of health care, particularly surgical services	Hospital records and routine health service statistics	Invasive procedures that meet the definition but are done in a procedure room not suitable for more extensive operations should not be considered in the total number of surgical procedures. If, however, they are done in the operating room, they should be counted
Day-of-surgery death ratio	Number of deaths on the day of surgery, irrespective of cause, divided by the number of surgical procedures in a given year or period, reported as a percentage	Day-of-surgery death ratios allow the health system to assess its performance and the state of health of the population	Administrative and hospital records based on health service statistics	Death on the day of surgery often reflects the comorbidities and physiological disorders of the patient, the quality and complexity of surgical care, or the risks of anaesthesia. It cannot be used to compare one site, facility, or country with another without appropriate, validated, and time-consuming risk adjustment
Perioperative in-hospital death ratio	Number of deaths in the hospital following surgery, irrespective of cause and limited to 30 days, divided by the number of surgical procedures done in a given year or period, reported as a percentage	Understanding the in-hospital death ratio after surgery provides insight into the risks associated with surgical intervention	Administrative and hospital records based on health service statistics	Patients who undergo surgery and die outside a health facility or after readmission to the same or a different facility are important to record in postoperative mortality assessments. Facilities should be encouraged to gather such information. Neither circumstance is included in this statistic, however

Table has been adapted from Weiser et al. [7]. A procedure is included in the count if it is performed within an operating facility and requires the administration of sedation or anaesthesia, whether local, regional, or general. To better interpret the contribution that a procedure makes to risk, the determining procedure ideally should be the first definitive procedure that a patient receives during an episode of care

discharge from hospital or within 30 days of surgery, whichever is sooner. These definitions of perioperative mortality have been previously proposed by the Safe Surgery Saves Lives initiative of WHO's Patient Safety Programme [13]. While the POMR, like MMR and other critical health indices, is not specific, it has the potential to be a valuable indication of surgical and anaesthesia safety. The two death measurements represent two standardized public health metrics for surgical care that are applicable worldwide and are further defined in Table 1 [7].

The POMR is expected to transcend country and cultural issues and allow comparison within and between countries and regions, with the potential to be used in similar fashion to the MMR.

Measuring POMR

POMR has the advantage that its numerator, death, is easily defined, and even in the most remote locations, it is either already recorded or there is great value in doing so. The

denominator is the number of procedures. A procedure is defined as one that takes place in an operating room or theatre suite. Some patients will have more than one procedure during a hospital admission so the total number of procedures will exceed the total number of patients. This is analogous to MMR, where the number of live births (denominator) will exceed the number of women having given birth. For input to the numerator, the outcome of death should be applicable only once, even for a patient who has multiple procedures.

There are a number of alternative time periods that could be used to report perioperative mortality. Death on the day of surgery was chosen instead of the alternatives: death within 24 or 48 h. Death on the day of surgery allows the use of the calendar day, avoiding having to calculate when 24 or 48 h has passed, and will include most or all deaths within the operating room. For those countries that have already established systems to report death within 24 or 48 h rather than on the day of surgery, there should be no difficulty in identifying those patients who die on the same calendar day. In acknowledgement of these different

time periods, one option would be to call this particular POMR 24, meaning 24 h. We believe there will be good correlation between rate on the day of surgery and rate in 24 h, though this remains to be proven by further study.

Death before discharge from hospital was chosen rather than within 30 days because of the challenge of following up patients after discharge in many parts of the world, particularly in developing countries whose hospitals serve remote and rural village populations. Recording a 30-day mortality rate may be achievable only in well-resourced countries that have the ability to conduct reliable postdischarge follow-up. In higher-income countries it may be possible to electronically link the Death Certification process to a hospital procedure, at least within the public health system. This would enable recording of postoperative deaths after discharge from hospital. It is acknowledged that 30-day mortality is often perceived as a standard and already reported in many countries, including some LMICs. It is particularly relevant at the level of a hospital or surgical service auditing mortality, where there is great value in continuing with 30-days as the cutoff rather than death before discharge to inform the continuous quality improvement process locally. However, for a credible indicator at the population level, many LMICs would struggle to report 30-day mortality. For these reasons we believe that POMR 30 should be the term used, but that death before discharge be used as a proxy for 30-day mortality where 30-day mortality rates are not currently feasible. Unpublished data suggest there is reasonable correlation between death before discharge when less than 30 days and death within 30 days, though this will require confirmation by further study.

In regions where hospitals transfer large numbers of cases after primary surgery to a referral hospital, the regional POMR will still reflect access to safe surgery and anaesthesia for the system as a whole. The individual hospital rate may require interpretation in the light of transfer patterns, but this should be achievable by the relevant lead clinicians and service managers.

Does POMR really measure access and safety?

Perioperative mortality is not only a measure of safety but also an indirect measure of access since the number of procedures performed must be known to calculate it. Lack of access to safe surgery and anaesthesia will result in delayed presentations, which correlate with both a higher mortality rate and fewer procedures. A system that fails with respect to both safety and access will have a higher mortality rate and fewer procedures per head of population. Further valuable information regarding access to surgical services may be gleaned by reporting the number of

procedures per 10,000 or 100,000 population. The procedures per population rate (PPR) will identify those hospitals that do few procedures and thus fall short in providing access to emergency and essential surgery. Other ways to measure access may still need to be considered, for example, the percentage of a population that has access to emergency and essential surgery within a particular time period. This may require agreeing to minimum standards as to how to deliver and what constitutes emergency and essential surgery. This latter option has the disadvantage of introducing more measures and being subject to point prevalence bias as to the time when any survey is conducted.

POMR and risk adjustment

POMR is a tool to evaluate care at the population level, rather than providing individual case review. Risk adjustment is required to compare POMR between jurisdictions. Collection of POMR should be expected of every country and region, and it is hoped that POMR reporting will become the norm for every member nation of WHO. Initially, not every hospital will be able to collect the necessary data to risk-adjust, but this will not diminish the importance of the identifying strategies to ensure this additional information can be derived. Ultimately, risk adjustment will be what convinces clinicians of the veracity of the data, whether they are surgeons, anaesthetists, or public health physicians.

Whatever method of risk adjustment is used, it needs to be simple yet robust. The necessary data must be easy to collect and preferably not require any laboratory tests, as these are not universally available. We recommend limiting risk adjustment of POMR to four simple variables: age, urgency (elective or emergency), name or code of procedure/procedure group, and American Society of Anesthesiologists (ASA) status [14, 15]. The ASA [physical status] score is simple, has been accepted for over 50 years, and has been shown to be applicable in LMICs as well as in the world's most developed G20 nations. The ASA score is a measure of comorbidity and physiological disturbance that does not have the complexity of the Elixhauser et al. [16] or Charlson et al. [17] comorbidity indices, for example, that require multiple variables and would be much more difficult, if not impossible, to roll out globally. Anaesthesia providers everywhere already use or can be taught to use ASA scoring. These advantages outweigh some potential limitations in precision or interrater consistency [18, 19].

New Zealand's Perioperative Mortality Review Committee (POMRC) has established a national framework for reporting perioperative mortality. They have stratified risk based on age, urgency of admission, ASA, and procedure

[11]. A large, multicentre, North American series based on the National Safety and Quality Improvement Program (NSQIP) reported that surgical mortality could be predicted on the basis of urgency, ASA, and a three-point grading of procedure risk into low, medium, or high [20]. The NSQIP data are strongly supportive of age being a significant predictor of risk for every decade over 65.

The POMR on the same day of surgery, as it is within 24 h of a procedure, is reflective of the clinical decision to perform a procedure at all, the ability to prepare and/or resuscitate a patient, the safety of the anaesthetic and procedure, and the immediate postoperative care and the ability to respond to clinical deterioration. A New Zealand review looked at the POMR on the day of the procedure and found an overall rate of 1 in 1,000 (0.1 %), with 5 in 1,000 (0.5 %) for emergency surgery and 0.22 per 1,000 (0.022 %) for elective surgery [11]. The review reported mortality was related to age and ASA [11, 21], but failed to demonstrate a relationship with ethnicity or deprivation index [11].

Misinterpreting perioperative mortality

There exists a risk of misinterpreting data. This was seen recently in Europe when a report of mortality after surgery was based on inaccurate data, resulting in embarrassment to the health services of a number of European countries. The report was purported to be a study of the outcome of surgery in a 7-day period and measured in-hospital mortality, duration of hospital stay, and admission to critical care [22]. There were wild fluctuations in perioperative mortality that should have alerted the authors as to the unreliability of their data collection method, with mortality ranging from an anticipated rate of 1.2 % to as high as 21.5 % in some countries. The article provoked a string of letters [23–27]. The actual mortality rates are more likely to be in the range of 0.5–1.2 %. For example, the POMR in Poland was actually 0.98 % of 22,000 operations and not the 17.5 % reported by the authors [25].

What POMR do we expect?

In 2008, clinical trials of WHO's surgical safety checklist in eight hospitals across the world reported a reduction in in-hospital mortality from 1.5 to 0.8 % and a drop in complications from 11 to 7 % [28]. The perioperative in-hospital mortality rate reported in the eight hospitals ranged from 0.28 to 1.45 % [7]. These findings were corroborated in the Netherlands where similar reductions in mortality (1.5–0.8 %) and complications (15.4–10.6 %) were reported [29]. It would be reasonable, based on the

above studies, to expect the POMR before discharge from hospital to be in the 0.5–1.5 % range, depending on the case mix. The actual rate will be determined by the proportion of emergency and elective procedures and the age and comorbidity of the patients (the latter is included in the ASA physical status score).

Bainbridge et al. [30] performed a systematic review and meta-analysis on perioperative and anaesthetic-related mortality in developed and developing countries. They described a tenfold reduction in perioperative mortality over the past 50 years with respect to deaths related to anaesthesia and total perioperative mortality, though much of this was attributable to improved results in developed countries. They reported a tenfold decline in POMR from 10,600 in 1,970–1,176 per million procedures in 1990–2000. During the same period, the anaesthesia-related mortality dropped from 357 to 34 per million procedures [30].

Perioperative mortality varies according to case mix, and therefore among specialties, particularly surgically remediable conditions such as fractured neck of femur or colorectal cancer. The literature contains a number of reports on perioperative mortality after cardiac, vascular, and general surgery, with the latter two specialties managing a high proportion of emergencies. Table 2 gives a selection of reported POMRs as a guide to what might be expected in developed nations, the very nations that would be expected to provide leadership in reporting POMR.

Although one might expect developing nations to report far higher rates, which is the current situation with IMR and MMR, a 30-day mortality rate following surgery in Zambia in 1990 was only 1.7 % [39], which is not that different from current day rates in the US of 1.4 % for general/vascular [40] and 1.32 % for noncardiac surgery [20].

Reviews of anaesthesia-related mortality in New South Wales, Australia (2006–2010), suggested that of 939 deaths within 24 h of an anaesthetic, <20 % were related to anaesthesia or have anaesthesia-related factors [40].

Mortality on the day of surgery or within 24 h (next day) has been reported by Médecins Sans Frontières (MSF) for nearly 20,000 operations in 13 countries between 2001 and 2008, of which 42 % were emergencies, with an impressive 0.2 % (range = 0–0.9 %) POMR [41]. The reported mortality rate within 24 h of surgery from sub-Saharan Africa suggests a rate of 0.2–0.6 % or 200–600 per 100,000 procedures or 1:150–1:500 anaesthetics (Table 3) [42–44].

The literature on POMR suffers due to lack of an agreed upon definition of early death and whether POMR should be reported on the day of surgery or within 24, 48 h, or 7 days. Anaesthesia-led studies have reported each of these different time periods. In Port Moresby, Papua New Guinea (2002), death within 48 h of anaesthesia was reported with

Table 2 Thirty-day mortality reported by condition or procedure from developed nations

Place	Year	Case mix	Number	Rate per 100 procedures	Reference
New Zealand	2005–2009	Acute admission for hip arthroplasty	7,443	7.3	POMRC NZ [11]
Australia, NSW	2000–2009	Hip fracture fixation	42,764	8.6	Harris et al. [31]
Australia	2010	Vascular	42,653	1.2	Beiles et al. [32]
Boston NSQIP	2002–2004	Colon	405	3.2	Gawande et al. [33]
Boston NSQIP	2004	General/Vascular	767	1.4	Gawande et al. [33]
ACS NSQIP	2005–2007	Noncardiac	298,772	1.34	Glance et al. [20]
ACS NSQIP	2005–2008	Colon, GB, hernia, pancreas	200,036	1.35	Vaid et al. [34]
Netherlands 90 hospitals	2010	Colon cancer	6,161	4.5	Kolfschoten et al. [35]
		Rectal cancer	2,419	2.3	
Japan 6 hospitals	1987–2007	Gastric cancer	1,708	2.6	Haga et al. [36]
UK—212 centres	2007	Upper GI bleeding	4,478	8.4	Jairath et al. [37]
Australia NSW	2000–2009	Hip arthroplasty	57,661	0.50	Harris et al. [31]
US	2000–2004	Hip arthroplasty	953,130	0.30	Liu et al. S[38]
New Zealand	2005–2009	Elective knee arthroplasty > 45	25,617	0.20	POMRC NZ [11]
New Zealand	2005–2009	Elective Colorectal	10,226	2.1	POMRC NZ [11]
		Emergency Colorectal		9.8	Table 15

Table 3 Mortality on day of surgery or within 24 h

Place	Year	Procedure	Sample	Rate per 100 procedures	Reference
New Zealand	2005–2009	Emergency general procedure	132,669	0.5313	POMRC [11]
New Zealand	2005–2009	Elective general procedure	1,032,114	0.0661	POMRC [11]
MSF Malawi	2001–2008	General and obstetric	19,643	0.157	Chu et al. [41]
Malawi	1999	All surgery within 6 months	3,022	0.463	Hansen et al. [42]
Togo	2006	All surgery	1,464	0.667	Ouru-Bang'na Mamam et al. [43]
Zimbabwe	1992	All surgery	34,553	0.258	McKenzie [44]

a rate of 1:333 or 30/10,000 procedures [45]. A detailed study of 7-day mortality from the University Teaching Hospital in Zambia in 1987 reported a mortality rate of 0.76 %, showing what can be expected in developing countries despite the lack of resources and different case mix [46]. Thirty-five of the 80 deaths were classed as anaesthetic-related. A 7-day mortality rate of 0.34 % was also reported from Malaysia: 715 deaths after 211,354 procedures over 2 years (1992–1994) [47]. Interestingly, in the Malaysian study, 27 and 46 % of deaths in the first 7 days occurred on the day of surgery or the following day. It should be noted that 7-day mortality will be lower than

that reported on discharge or at 30 days, though any relationship between 7- and 30-day mortality has not been widely reported. We recommend choosing the same calendar day of surgery rather than within 24 h.

We believe a POMR based on the number of deaths on the day of the procedure will be indicative of deaths arising from late presentation, poor decision making, inadequate resources (including human resources), inadequate preoperative preparation, and unsafe anaesthesia. Other causes of death, including the aforementioned five causes, will also be identified by reporting the in-hospital POMR (before discharge or within 30 days), as an admission outcome.

Learning from perioperative mortality review

There is an opportunity for developed nations and referral hospitals in developing countries to take a lead in reporting perioperative mortality. We do not believe this will involve significant resources as the information is already being collected in some form in most hospitals. Ministries of Health will need to mandate that all hospitals report this information. Collecting and reporting POMR will impact only surgical and anaesthesia outcomes when reporting is mandatory and benchmarking is put into place for measuring the impact of interventions made within a surgical system. The pivotal point in the healthcare system in LMICs is at the District or First Referral Hospital where the needs are greatest. WHO has long recommended emergency and essential surgery be available at the District Hospital level. Yet, recent reports suggest that when surveyed, many of these hospitals do not provide access to safe surgery and anaesthesia when needed, even for trauma, obstructed labour, or abdominal emergencies, all conditions that present locally and require urgent treatment to prevent disability and death.

Eventually, of course, the POMR analysis will not result in improvements in the standards of anaesthesia and surgery unless review of individual cases takes place. The Scottish Audit of Surgical Mortality [48] and Confidential Enquiry into Perioperative Deaths (CEPOD) [49–51] are examples of how such reviews in developed nations can drive improvement. Audits of anaesthesia-related (within 24 h) and surgically related mortality have also resulted in improved quality of care in Australia [44] and resulted in reductions in mortality of surgical patients [52, 53].

Reviews of deaths within 24 h of surgery and anaesthesia in the State of New South Wales and elsewhere in Australia suggest that up to a quarter of deaths in the first 24 h are anaesthesia-related [32, 54]. The problems of anaesthesia delivery in developing countries can be defined [55, 56] and standards of safe anaesthesia have been established [57]. Similarly, there are tools and methodologies that can be used to assess surgical capability and capacity [8, 9, 58]. This suggests that, with a measure of access (possibly procedures per 100,000 population) and safety (POMR), there is the prospect of improving the quality of care for people requiring emergency and essential surgery.

Access to safe surgery and anaesthesia when needed

Safe surgery and anaesthesia are not unaffordable luxuries reserved only for the health systems of high-income countries. They should be seen as an essential component within the Sustainable Development Goal of Universal

Health Coverage. Everyone deserves them and their lack represents a significant cost in terms of life and disability to the communities that cannot access them. There are an increasing number of studies that suggest that surgery and anaesthesia can be delivered in LMICs both effectively and inexpensively, often at a cost (\$11–35 per disability-adjusted life-year [DALY] averted) similar to that for measles vaccination, vitamin A supplementation, or bed nets to prevent malaria [59–63]. Therefore, the surgical management of injuries, infection, obstetric and abdominal emergencies, and many types of deformity is cost-effective and thus potentially deliverable for all. It is possible to provide safe surgery and anaesthesia cost-effectively, but to do so requires a commitment to provide the necessary facilities, resources, and skilled workforce. We believe POMR will draw attention to the need to do so and, in time, will be a credible [64] means of measuring improvement.

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