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Systematic review of the use of big data to improve surgery in low- and middle-income countries

S. R. Knight1, R. Ots1, M. Maimbo2, T. M. Drake1, C. J. Fairfield1 and E. M. Harrison1

1Surgical Informatics, Centre for Medical Informatics, Royal Infirmary of Edinburgh, University of Edinburgh, Edinburgh, UK, and 2Department of General Surgery, Kitwe Teaching Hospital, Kitwe, Zambia

Correspondence to: Mr E. M. Harrison, Department of Clinical Surgery, University of Edinburgh, 51 Little France Crescent, Edinburgh EH16 4SA, UK (e-mail: ewen.harrison@ed.ac.uk; @sr_knight1, @RiinuOts, @mayabamaimbo, @Tom_Drake1, @c_j_fairfield, @ewenharrison)

Background: Technological advances have led to the generation of large amounts of data, both in surgical research and practice. Despite this, it is unclear how much originates in low- and middle-income countries (LMICs) and what barriers exist to the use of such data in improving surgical care. The aim of this review was to capture the extent and impact of programmes that use large volumes of patient data on surgical care in LMICs.

Methods: A PRISMA-compliant systematic literature review of PubMed, Embase and Google Scholar was performed in August 2018. Prospective studies collecting large volumes of patient-level data within LMIC settings were included and evaluated qualitatively.

Results: A total of 68 studies were included from 71 LMICs, involving 708,032 patients. The number of patients in included studies varied widely (from 335 to 428,346), with 25 reporting data on 3,000 or more LMIC patients. Patient inclusion in large-data studies in LMICs has increased dramatically since 2015. Studies predominantly involved Brazil, China, India and Thailand, with low patient numbers from Africa and Latin America. Outcomes after surgery were commonly the focus (33 studies); very few large studies looked at access to surgical care or patient expenditure. The use of large data sets specifically to improve surgical outcomes in LMICs is currently limited.

Conclusion: Large volumes of data are becoming more common and provide a strong foundation for continuing investigation. Future studies should address questions more specific to surgery.

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Introduction

The concept of ‘big data’ describes the use of unstructured digital information, usually from multiple sources, that is often collected with no clearly defined purpose for future use1. The volume of data already being produced is vast, with frequent increases in complexity, variety and speed2. Big data in surgery can be defined as the amalgamation and integration of various data sources along the patient pathway to produce a rich matched data set (Fig. 1).

The analysis and translation of big data to maximize quality and improve patient care is a priority for healthcare systems3. It is envisaged that measurement and modelling of patient health states and outcomes will quickly become the biggest driver of best practice and healthcare policy4. Continual analysis of patient-level outcomes has already been demonstrated to significantly reduce morbidity and mortality in high-income countries5.

However, discussions around large-volume patient data frequently place little emphasis on their application in low- and middle-income countries (LMICs), despite the potential for vast gains in patient outcomes and surgical service quality7. Currently, LMICs may lack the ability to gather reliable data6, with an expectation that this situation is unlikely to change in the near future8,9. Ensuring that LMICs can keep up to date with technological advances will help to prevent future global health inequalities worsening10.

The aim of this review was to evaluate the current applications of large-volume patient-level data in surgery in LMICs, together with highlighting where further focus is required to improve outcomes, define quality indicators and achieve universally available safe surgery.
Fig. 1 Conceptualizing big data in healthcare. Health system data are aggregated with data generated by the individual and their environment. Data are transformed and analysed to generate actionable output.

**Methods**

An electronic systematic search of the PubMed, Embase and Google Scholar databases was performed in accordance with the PRISMA guidelines\(^1\), involving all published literature up to the last search on 23 August 2018. The PROSPERO international systematic review registry\(^2\) was searched to ensure a similar review had not been performed previously and the protocol was registered accordingly (CRD42018108203).

A search of Embase and PubMed was undertaken using the keywords ‘surgery or surg\(^*\)’, ‘big data’, ‘large data’, ‘informatics’, ‘database’, ‘cohort’ and ‘registry’, combined with LMIC filters as specified by the Cochrane library\(^3\). Search terms are listed in Appendix S1 (supporting information). A further supplementary search of Google Scholar was also undertaken. Search limits applied were English language, full text, humans and articles published from 2008 onwards to provide contemporary studies that were likely reflective of current approaches to data capture.

The inclusion criteria were: prospectively collected data (or retrospective analysis of such data) on patients undergoing surgery with care being provided, at least in part, in a LMIC, defined according to the World Bank classification\(^4\). Studies were excluded if they contained fewer than 100 patients or were RCTs. Conference abstracts were screened to assist in identifying related full-text articles. Where more than one article was published from a single data set, the article analysing the largest cohort of patients was included.
Following the literature search, article titles were screened by four investigators and those meeting the inclusion criteria were screened further by abstract and then full text as appropriate. Any disagreements were resolved by consensus within the group. Bibliographies from included articles were hand-searched to identify any further relevant articles.

Data were extracted independently using a standardized pro forma, including year of publication, countries involved in the study, number of patients for each LMIC, patient-level data type (cohort, database or registry), surgical specialty and measured outcome(s). In multinational studies where the number of patients for individual countries was not reported, the number of patients in the study was recorded. These studies were excluded from analysis mapping of the global distribution of patients across included studies to avoid data skewing. Individual LMICs where there were fewer than 100 patients in multinational studies were also excluded from analysis mapping. However, studies that did not report patient numbers for individual LMICs and all data from multinational studies were included in all other analyses.

Data types were defined as follows: cohort – collection of patient-level data over a defined short period; database – concerted and long-term collection of patient-level data of consecutive patients over a small geographical area; or registry – studies meeting database classification but performed over a wide geographical area (such as national registries).

Definitions were discussed and consensus reached within the group where doubt existed regarding particular studies. Owing to the narrative nature of the review, a qualitative analysis was performed using the R statistical program (https://www.R-project.org/) and the tidyverse package\(^\text{15}\). All analyses and graphical representation of the data can be found at https://argoshare.is.ed.ac.uk/bigdata_review.
The literature search identified 3805 articles, of which 218 full texts were assessed for eligibility (Fig. 2). Following assessment, 68 articles involving 708 032 patients across 71 LMICs were included in the review (Tables S1 and S2, supporting information). Country-specific patient numbers were reported in 60 studies but were absent from six50–52,57,62,83 and two33,55 provided total LMIC patient numbers only.

Patients and studies

Studies using big data were well represented across the 10-year analysis period; however, a dramatic increase in study and patient numbers was seen from 2015 onwards (Fig. 3a). Relatively few studies were found for the interval 2012–2014 despite no decrease in the total number of studies returned in the initial literature search (339, 358 and 469 studies in 2012, 2013 and 2014 respectively, compared with a median of 222 (range 129–487) for other years).

The number of patients in the included studies ranged from 335 to 428 346, with a median of 2483 per study. Over 3000 patients were included in 25 of 68 studies; the biggest studies were published in the interval 2015–2018. Studies based on database and registry data were most common and represented 43 of 68 included studies. The majority of data sets identified arose from prospective cohorts of patients. Several of these studies were performed in single centres43,65 or single nations79,81, with comparisons made with high-income countries. The largest cohort of patients originated from the DATASUS registry in Brazil (428 346 patients), which explored outcomes after hysterectomy80.

Five multinational observational cohort studies50,51,57,82,83 were performed in the past 5 years, with the majority conducted over 7 days.

Geographical distribution

The studies had a wide geographical LMIC distribution. The majority, however, were from Brazil (12), China (11), India (5) and Thailand (4) (Fig. 4a). Patient-level data were collected from 71 LMICs in total; overall, patient representation was particularly low in Africa and Latin America (Fig. 4b).

Subject of studies

The focus of study varied across included articles (Fig. 5). Short-term outcomes of surgery were most commonly captured (33 studies) and, of these studies, eight included over 10 000 patients each.

Outcomes following cancer surgery were common topics, including breast39,31,38,45–47,77, gastric16,22,23,61, colorectal13,59,76,81 and prostate18,30 cancer, and hepatocellular carcinoma36,60. Cardiac surgery34,43,65,70, caesarean section44,49,69 and genitourinary fistula27,33,74 were also well represented in included articles, whereas clinical presentations included burn management55, trauma66.
Fig. 4 Global distribution of patients and studies across low- and middle-income countries (LMICs) in included articles (2008 to present). a Number of studies and b number of patients in studies of LMICs. Countries with fewer than 100 patients recruited for a multinational study were excluded from a, as were studies in which LMIC-specific patient numbers were not specified.

Fig. 5 Subject area of large-volume studies of surgery in low- and middle-income countries in relation to number of study patients

appendicitis, groin hernias and orthopaedic fracture management.

However, the overall journey of a patient through the surgical care process was poorly represented, with only a single study examining access to surgical care and the cost of surgical care to the patient. No study assessed whether the results of big data analyses have resulted in meaningful changes to healthcare systems or had a significant impact on patient outcomes in LMIC settings.
A number of studies successfully demonstrated the ability to assemble large prospective data sets on patients across multiple nations. The International Surgical Outcomes Study\textsuperscript{51} included 15,806 patients in eight LMICs, and the African Surgical Outcomes Study\textsuperscript{82} included 11,422 patients across 25 African countries. These studies captured mortality and complication rates but, as importantly, were able to capture patient risk profiles and patterns of surgical practice. Highlighting differences in surgical outcome by country-income level, a lack of critical care provision in LMICs was postulated to significantly influence the ability to rescue patients from complications, with implications for resource planning at a governmental level\textsuperscript{40,51,82}.

Multinational studies also targeted specific disease areas (GlobalSurg 1: emergency abdominal surgery)\textsuperscript{57} or specific complications of surgery (GlobalSurg 2: surgical-site infection)\textsuperscript{83}. These two studies\textsuperscript{57,83} gathered prospective data on 23,284 patients and demonstrated that low-income countries carry a disproportionately higher burden of surgical-site infection and threefold higher mortality rates.

### Discussion

The past 5 years has seen an exponential rise in the number of patients included in studies from LMICs, with some very large cohorts in countries such as Brazil, China and India. Geographical disparities are apparent and are particularly obvious in Africa, where far fewer large studies have been published. The focus is predominately on short-term outcomes after surgery, together with the epidemiology of diseases commonly treated by surgery. Few studies have focused on the specific needs of resource-poor environments. It is perhaps too early to determine any positive effects of such work on outcomes in populations of individuals receiving surgical care.

The use of big data to capture patient-level outcomes in an LMIC setting has increased exponentially over the past 10 years. However, in global cohort studies the proportion of patients recruited from high-income countries remains much greater\textsuperscript{51,57,83}. This may suggest the limiting role of infrastructure and resources within LMICs in collecting patient data. Huge disparity with big data applications currently exists globally; no included studies used big data algorithms to identify patient management, predict outcome or direct healthcare policy.

In high-income settings, big data are currently the focus of genomewide data analysis\textsuperscript{84}, developing personal omics profiles\textsuperscript{85} and individualized oncology treatment\textsuperscript{86}. Meanwhile machine-learning algorithms are being developed to help deliver care, inform health policy and reduce waste\textsuperscript{87–89}. Technological infrastructure, specialized analytical skills and personal tracking of health statistics using smart phones, particularly in America, is enabling the amalgamation and analysis of big data from multiple sources on an individual level to offer personalized healthcare packages\textsuperscript{80}. However, real-time mobile technology application to measure infectious disease outbreaks in LMICs has been realised\textsuperscript{91,92}, and efforts to develop and incorporate multiple levels of patient data should now be a focus.

Combining data from multiple sources to draw population-level conclusions worldwide is epitomized by the Global Burden of Disease project by the Institute for Health Metrics and Evaluation at the University of Washington. This is a global effort to examine comprehensively the prevalence, incidence and impact of multiple diseases and environmental factors using an extensive network of more than 2500 collaborators from 133 countries\textsuperscript{93}. Recent publications include global predictions on cancer burden\textsuperscript{94}, child mortality\textsuperscript{95}, causes of adult disability\textsuperscript{96} and alcohol use\textsuperscript{97}.

Such projects require accurate national data, which do not exist in many regions. National registries can be expensive to establish and run, but are becoming more common in middle-income countries, such as the Chinese Guangzhou Occupational Cohort\textsuperscript{98} and the Brazilian DATASUS registry\textsuperscript{80}.

Comprehensive patient-level databases or registries are yet to be adopted in the majority of LMICs. Barriers limiting broad adoption include a lack of resources and infrastructure, such as electricity and reliable internet connectivity, combined with skill shortages in medical informatics. The advent of the electronic patient record (EPR) may present the best opportunity for routine data analysis at a health-system level\textsuperscript{99}. Although the costs of set-up and maintenance can be a barrier, multiple open-source EPRs now exist which can potentially alleviate some of these\textsuperscript{100}. Recently, Rwanda announced the roll-out of the OpenMRS system to 250 clinics and hospitals across the country\textsuperscript{101}. This will bring EPRs into national practice and offer the opportunity for real-time data collection within a healthcare system to be used for infrastructure planning and research.

Linked to this is the explosion in mobile phone technology. Three-quarters of the population of sub-Saharan Africa already lives in an area with mobile internet connectivity\textsuperscript{102}. On-board sensors within mobile phones offer the ability to capture data remotely, without the need for specialized equipment. The increasing availability of mobile phone use is already supplementing existing forms of patient data, particularly in high-income settings. In surgery, this presents exciting avenues for diagnosis and
routine follow-up, particularly in settings where patients cannot easily attend hospitals.

There are important areas of study that are more specific to resource-poor areas, such as access to surgical care and the cost of surgical care to patients. Only one study,\(^7\) was identified that explored the economic consequences of surgery; this reflected previous findings highlighting large-scale health economic studies in cancer being focused in high-income countries or heavily modelled using data from high-income countries.\(^10\) Evaluating patient cost following surgery is likely to require frequent and long-term follow-up, potentially explaining the difficulties in measuring this outcome. Use of mobile technology to circumvent current logistical issues and capture expenditure data following surgery is an exciting avenue.

The landscape of healthcare data is changing rapidly. Ensuring that LMICs have the resources to keep up to date with technological advances will ensure future global health equality.\(^11\) New developments, such as artificial intelligence, virtual reality, mobile computing and new molecular techniques, present exciting opportunities for surgeons across the world. Embedding these technologies within ‘learning’ healthcare systems will ensure that data contribute to the incremental development of safe practice. Big data are capable of providing information on safety, complications and survival; however, with the increasing use of big data, care must be taken to account for unknown and unrecognized confounders in order to determine intervention effectiveness and provide strong observational conclusions.\(^12\)

In parallel with future advances, ensuring that electronic data are kept secure is of utmost importance. Respecting an individual patient’s rights to confidentiality, autonomy and privacy is fundamental to ensuring public trust in electronic data collection methods. Beyond good data governance practice, technologies such as blockchain may facilitate the safe and secure sharing of healthcare data within increasingly complex interconnected systems.

There are weaknesses to the approach taken in this review. Pragmatic limitations around the scope of the review search were required and important studies may have been omitted. The synthesis of such a heterogeneous group of studies is difficult and conclusions must be made at a high level.

This review has demonstrated a significant growth in the use of large-volume patient-level data across many surgical specialties and LMICs. At least 71 LMICs currently involved in big data projects were identified, with evidence of an exponential growth in patient numbers totalling more than 700,000. However, to date, the majority of studies using big data have been limited to short-term outcomes after surgery and few have addressed the needs that are particular to LMICs. Funders, policymakers and specialists in medical informatics urgently need to reorientate this focus if the potential of big data to improve surgical outcomes, particularly in LMICs, is to be realized fully.

**Disclosure**

The authors declare no conflict of interest.

**References**

1. Vedula SS, Hager GD. Surgical data science: the new knowledge domain. *Innov Surg Sci* 2017; 2: 109–121.
2. Pence HE. What is big data and why is it important? *J Educ Technol Syst* 2014; 43: 159–171.
3. McCue ME, McCoy AM. The scope of big data in one medicine: unprecedented opportunities and challenges. *Front Vet Sci* 2017; 4: 194.
4. Bloomrosen M, Detmer DE. Informatics, evidence-based care, and research; implications for national policy: a report of an American Medical Informatics Association health policy conference. *J Am Med Inform Assoc* 2010; 17: 115–123.
5. Targarona EM, Balla A, Batista G. Big data and surgery: the digital revolution continues. *Cir Exp* 2018; 96: 247–249.
6. Khuri SF, Daley J, Henderson W, Hur K, Demakis J, Aust JB *et al.* The Department of Veterans Affairs’ NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. *Ann Surg* 1998; 228: 491–507.
7. Curado MP, Voti L, Sortino-Rachou AM. Cancer registration data and quality indicators in low and middle income countries: their interpretation and potential use for the improvement of cancer care. *Cancer Causes Control* 2009; 20: 751–756.
8. Taylor L, Schroeder R. Is bigger better? The emergence of big data as a tool for international development policy. *GeoJournal* 2015; 80: 503–518.
9. Jerven M. Poor Numbers: How We Are Misled by African Development Statistics and What to Do About It. Cornell University Press: Ithaca, 2013.
10. Drake TM, Knight S, Harrison EM, Søreide K. Global inequities in precision medicine and molecular cancer research. *Front Oncol* 2018; 8: 346.
11. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; 6: e1000097.
12. PROSPERO: International prospective register of systematic reviews; 2018. [https://www.crd.york.ac.uk/prospero/](https://www.crd.york.ac.uk/prospero/) [accessed 30 August 2018].
13 Cochrane Effective Practice and Organization of Care. LMIC Filters; 2018. https://epoc.cochrane.org/lmic-filters [accessed 30 August 2018].
14 The World Bank. World Bank Country and Lending Groups – World Bank Data Help Desk. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519 [accessed 30 August 2018].
15 Wickham H. Tidyverse: Easily Install and Load the ‘Tidyverse’. R package version 1.2.1; 2017. https://CRAN.R-project.org/package=tidyverse [accessed 27 August 2018].
16 Moghimi-Dehkordi B, Safaee A, Zali MR. Survival rates and prognosis of gastric cancer using an actuarial life-table method. Asian Pac J Cancer Prev 2008; 9: 317–321.
17 Zhaohui S, Shuxia Z, Xinghua F, Shujun L, Yanpu L, Bin B et al. The design and implementation of Chinese maxillofacial trauma registry, analysis and injury severity score system. J Trauma 2008; 64: 1024–1033.
18 Mariano MB, Tefilli MV, Fonseca GN, Goldraich IH. Laparoscopic radical prostatectomy: 10 years experience. Int Braz J Urol 2009; 35: 565–572.
19 Rezaianzadeh A, Peacock J, Reidpath D, Talei A, Hosseini SV, Mehrabani D. Survival analysis of 1148 women diagnosed with breast cancer in Southern Iran. BMC Cancer 2009; 9: 168.
20 Campos FG, Valarini R. Evolution of laparoscopic colorectal surgery in Brazil: results of 4744 patients from the national registry. Surg Laparosc Endosc Percutan Tech 2009; 19: 249–254.
21 Elbasmi AA, Fayaz MS, Al-Mohanadi S, Al-Nesf Y, Al-Awadi A. Reliability of the Kuwait Cancer Registry: a comparison between breast cancer data collected by clinical oncologists and registry staff. Asian Pac J Cancer Prev 2010; 11: 735–738.
22 Biglarian A, Hajizadeh E, Kazemnejad A, Zayeri F. Determining of prognostic factors in gastric cancer patients using artificial neural networks. Asian Pac J Cancer Prev 2010; 11: 533–536.
23 Moghimi-Dehkordi B, Safaee A, Fatemi R, Ghiasi S, Zali MR. Impact of age on prognosis in Iranian patients with gastric carcinoma: review of 742 cases. Asian Pac J Cancer Prev 2010; 11: 335–338.
24 Chen CQ, Fang LK, Cai SR, Ma JP, Yang GX, Yang W et al. Effects of diabetes mellitus on prognosis of the patients with colorectal cancer undergoing resection: a cohort study with 945 patients. Chin Med J (Engl) 2010; 123: 3084–3088.
25 Gupta NP, Ishwari R, Kumar A, Dogra PN, Seth A. Renal tumors presentation: changing trends over two decades. Indian J Cancer 2010; 47: 287–291.
26 Latin American Pediatric Nephrology Association; Latin American Pediatric Renal Transplant Cooperative Study. Latin American Registry of Pediatric Renal Transplantation 2004–2008. Pediatr Transplant 2010; 14: 701–708.
27 Muleta M, Rasmussen S, Kiserud T. Obstetric fistula in 14928 Ethiopian women. Acta Obstet Gynecol Scand 2010; 89: 945–951.
41 Moodley Y, Biccard BM. Predictors of in-hospital mortality following non-cardiac surgery: findings from an analysis of a South African hospital administrative database. S Afr Med J 2015; 105: 126–129.

42 Zablotska LB, Nadyrov EA, Rozhko AV, Gong Z, Polyanskaya ON, McConnell RJ et al. Analysis of thyroid malignant pathologic findings identified during 3 rounds of screening (1997–2008) of a cohort of children and adolescents from Belarus exposed to radioiodines after the Chernobyl accident. Cancer 2015; 121: 457–466.

43 Saifuddin A, Shahabuddin S, Perveen S, Furnaz S, Sharif H. Towards excellence in cardiac surgery: experience from a developing country. Int J Qual Health Care 2015; 27: 255–259.

44 Filippi V, Ganaba R, Calvert C, Murray SF, Storeng KT. After surgery: the effects of life-saving caesarean sections in Burkina Faso. BMC Pregnancy Childbirth 2015; 15: 348.

45 Sangkittipaiboon S, Leklob A, Sriplung H, Bilheem S. Breast cancer in Lopburi, a province in Central Thailand: analysis of 2001–2010 incidence and future trends. Asian Pac J Cancer Prev 2015; 16: 8359–8364.

46 Lalitwongsa S, Pongnikorn D, Daoprasert K, Sriplung H, Tassanasunthornwong S, Chansaard W, Sriplung H, Islam MT, Yoshimura Y. Rate of cesarean delivery at a South African hospital administrative database. BMC Pregnancy Childbirth 2015; 16: 6735–6740.

47 Tassanasunthornwong S, Chansaard W, Sripung H, Bilheem S. Breast cancer in Surat Thani, a province in Southern Thailand: analysis of 1993–2012 incidence and future trends. Asian Pac J Cancer Prev 2015; 16: 8327–8333.

48 Paula Fde L, da Cunha GM, Leite Ida C, Pinheiro RS, Valent JG. Elderly readmission and death after discharge from treatment of hip fracture, occurred in public hospitals from 2008 to 2010, Rio de Janeiro. Rev Bras Epidemiol 2015; 18: 439–453.

49 Islam MT, Yoshimura Y. Rate of cesarean delivery at hospitals providing emergency obstetric care in Bangladesh. Int J Gynaecol Obstet 2015; 128: 40–43.

50 Moreno RP, Pearse R, Rhodes A; European Surgical Outcomes Study (EuSOS) Group of the European Society of Intensive Care Medicine and European Society of Anaesthesiology Trials Groups. American Society of Anaesthesiologists score: still useful after 60 years? Results of the EuSOS study. Rev Bras Ter Intensiva 2015; 27: 105–112.

51 International Surgical Outcomes Study group. Global patient outcomes after elective surgery: prospective cohort study in 27 low-, middle- and high-income countries. Br J Anaesth 2016; 117: 601–609.

52 Nagoshi N, Tetreault LA, Nakashima H, Nouri A, Arnold P, Zileli M et al. Do Caucasians and East Asians have different outcomes following surgery for the treatment of degenerative cervical myelopathy?: results from the prospective multicenter AOSpine International Study. Spine (Phila Pa 1976) 2016; 41: 1428–1435.

53 Tostes MF, Covre ER, Fernandes CA. Access to surgical assistance: challenges and perspectives. Rev Lat Am Enfermagem 2016; 24: e2677.

54 Wang P, Huang G, Tam N, Wu C, Fu S, Hughes BP et al. Influence of preoperative sodium concentration on outcome of patients with hepatitis B virus cirrhosis after liver transplantation. Eur J Gastroenterol Hepatol 2016; 28: 1210–1215.

55 Garcia LP, Huang A, Corlew DS, Aeron K, Aeron Y, Rai SM et al. Factors affecting burn contracture outcome in developing countries: a review of 2506 patients. Ann Plast Surg 2016; 77: 290–296.

56 Xiang L, Li J, Chen J, Wang X, Guo P, Fan Y et al. Prospective cohort study of laparoscopic and open hepatectomy for hepatocellular carcinoma. Br J Surg 2016; 103: 1895–1901.

57 GlobalSurg Collaborative. Mortality of emergency abdominal surgery in high-, middle- and low-income countries. Br J Surg 2016; 103: 971–988.

58 Nandakumar A, Nandakumar A. Survival in head and neck cancers – results of a multi-institution study. Asian Pac J Cancer Prev 2016; 17: 1745–1754.

59 Reyes PA, Gabriel EA. Incidence, prevalence, mortality, risks, and survival of colorectal carcinoma in metro Cebu from 2002 to 2012: a 10-year analysis. J Gastroenterol Hepatol 2016; 31: 192.

60 Lei Z, Li J, Wu D, Xia Y, Wang Q, Si A et al. Nomogram for preoperative estimation of microvascular invasion risk in hepatitis B virus-related hepatocellular carcinoma within the Milan criteria. JAMA Surg 2016; 151: 356–363.

61 Bhandare MS, Kumar NAN, Batra S, Chaudhari V, Shrikhande SV. Radical gastrectomy for gastric cancer at Tata Memorial Hospital. Indian J Cancer 2017; 54: 605–608.

62 Acaroglu E, Guler UO, Cetinyurek-Yavuz A, Yuksel S, Yavuz Y, Ayhan S et al.; European Spine Study Group. Decision analysis to identify the ideal treatment for adult spinal deformity: what is the impact of complications on treatment outcomes? Acta Orthop Traumatol Turc 2017; 51: 181–190.

63 Fang C, Wang W, Zhang Y, Feng X, Sun J, Zeng Y et al. Clinopathologic characteristics and prognosis of gastroenteropancreatic neuroendocrine neoplasms: a multicenter study in South China. Chin J Cancer 2017; 36: 51.

64 Figueiredo AE, de Mattos C, Saraiva C, Olandoski M, Barretti P, Pecoits Filho R et al.; all BRAZPD II Investigators. Comparison between types of dressing following catheter insertion and early exit-site infection in peritoneal dialysis. J Clin Nurs 2017; 26: 3658–3663.

65 Zheng Z, Zhang H, Yuan X, Rao C, Zhao Y, Wang Y et al. Comparing outcomes of coronary artery bypass grafting among large teaching and urban hospitals in China and the United States. Circ Cardiovasc Qual Outcomes 2017; 10: e003327.
66 Yousefzadeh Chabok S, Ranjar Taklimie F, Malekpouri R, Razzaghi A. Predicting mortality, hospital length of stay and need for surgery in pediatric trauma patients. Chin J Traumatol 2017; 20: 339–342.

67 Gajewski J, Dharamshi R, Strader M, Kachimba J, Borgstein E, Mwapasa G et al. Who accesses surgery at district level in sub-Saharan Africa? Evidence from Malawi and Zambia. Trop Med Int Health 2017; 22: 1533–1541.

68 Shah S, Ross O, Pickering S, Knoble S, Rai I. Tablet e-Logbooks: four thousand clinical cases and complications e-Logged by 14 nondoctor anesthesia providers in Nepal. Anesth Analg 2017; 125: 1337–1341.

69 Hu Y, Huang K, Sun Y, Wang J, Xu Y, Yan S et al. ACTION Study Group. Policy and priorities for national metastasis and disease-free survival comparison between JT r a u m a t o l need for surgery in pediatric trauma patients. Razzaghi A. Predicting mortality, hospital length of stay and outcomes in a South African population. Rev Lat Am Enfermagem 2015; 23: 118–122.

70 Arthur CPS, Mejia OAV, Osternack D, Nakazone MA, Goncharov M, Lisboa LAF et al.; Grupo de Estudo REPLICCAR. Do we need to personalize renal function assessment in the stratification of patients undergoing cardiac surgery? Arq Bras Cardiol 2017; 109: 290–298.

71 Hernandez MC, Kong VY, Aho JM, Bruce JL, Polites SF, Doshi P, Gopalan H, Sprague S, Pradhan C, Kulkarni S, Treeprasertsuk S, Poovorawan K, Soonthornworasiri N, Kopp DM, Bengtson AM, Tang JH, Chipungu E, Moyo M, Wang K, Zhang X, Zheng K, Yin XD, Xing L, Zhang AJ

86 IBM Watson for Oncology. Overview – United States, 2018. https://www.ibm.com/us-en/marketplace/ibm-watson-for-oncology [accessed 3 October 2018].

87 Belle A, Thiagarajan R, Soroushmehr SM, Navidi F, Beard DA, Najarian K. Big data analytics in healthcare. Br Med Res Int 2015; 2015: 370194.

88 GlobalSurg Collaborative. Surgical site infection after gastrointestinal surgery in high-income, middle-income, and low-income countries: a prospective, international, multicentre cohort study. Lancet Infect Dis 2018; 18: 516–525.

89 Murdoch TB, Detsky AS. The inevitable application of big data to improve surgery in low- and middle-income countries: lessons from the Association of Southeast Asian Nations (ASEAN) Costs in Oncology prospective cohort study. BJOG 2019; 106: e62–e72.
93 GHDx. Global Burden of Disease Study 2016 (GBD 2016) Data Resources. http://ghdx.healthdata.org/gbd-2016 [accessed 30 August 2018].

94 Global Burden of Disease Cancer Collaboration, Fitzmaurice C, Akinyemiju TF, Al Lami FH, Alam T, Alizadeh-Navaei R et al. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 1990 to 2016: a systematic analysis for the global burden of disease study. *JAMA Oncol* 2018; 4: 1553–1568.

95 GHDx. Global Burden of Disease Study 2016 (GBD 2016) All-cause Under-5 Mortality, Adult Mortality, and Life Expectancy 1970–2016. http://ghdx.healthdata.org/record/global-burden-disease-study-2016-gbd-2016-all-cause-under-5-mortality-adult-mortality-and [accessed 30 August 2018].

96 GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017; 390: 1211–1259.

97 GBD 2016 Alcohol Collaborators. Alcohol use and burden for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2018; 392: 1015–1035.

98 Lin JH, Jiang CQ, Ho SY, Zhang WS, Mai ZM, Xu L et al. Smoking and nasopharyngeal carcinoma mortality: a cohort study of 101 823 adults in Guangzhou, China. *BMC Cancer* 2015; 15: 906.

99 Reisman M. EHRs: the challenge of making electronic data usable and interoperable. *PT* 2017; 42: 572–575.

100 Syzdykova A, Malta A, Zolfo M, Diro E, Oliveira JL. Open-source electronic health record systems for low-resource settings: systematic review. *JMIR Mod Inform* 2017; 5: e44.

101 OpenMRS Wiki. Rwanda PIH–MoH Collaboration – Projects. https://wiki.openmrs.org/display/projects/Rwanda+PIH++MoH+Collaboration [accessed 30 Aug 2018].

102 GSMA. The Mobile Economy 2018. https://www.gsma.com/mobileeconomy/ [accessed 2 September 2018].

103 Sullivan R, Alatise OI, Anderson BO, Audisio R, Autier P, Aggarwal A et al. Global cancer surgery: delivering safe, affordable, and timely cancer surgery. *Lancet Oncol* 2015; 16: 1193–1224.

104 Maruthappu M, Watkins J, Noor AM, Williams C, Ali R, Sullivan R et al. Economic downturns, universal health coverage, and cancer mortality in high-income and middle-income countries, 1990–2010: a longitudinal analysis. *Lancet* 2016; 388: 684–695.

105 Glasziou P, Chalmers I, Rawlins M, McCulloch P. When are randomised trials unnecessary? Picking signal from noise. *BMJ* 2007; 334: 349–351.

Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.