

Derivation of a complication burden score based on disability-adjusted life years to assess patient burden following surgery: a pilot study

Sadaf Mohtashami, MSc
Nadia Safa, MDCM
Elena Guadagno, MLIS
Robert Baird, MSc, MDCM
Dan Poenaru, MD, PhD

Accepted Jan. 21, 2020

Correspondence to:

D. Poenaru
Harvey E. Beardmore Division
of Pediatric Surgery
Montreal Children's Hospital
McGill University Health Centre
Montréal QC H4A 3J1
dan.poenaru@mcgill.ca

DOI: 10.1503/cjs.004819

Background: Comparing adverse outcomes following alternative surgical interventions is a complex process for both patients and providers. Disability-adjusted life years (DALYs) are used globally as a quantitative indicator of burden of disease. However, DALYs have not been applied to the burden of postoperative complications. This study explores the feasibility and utility of DALYs in measuring the burden of postoperative complications, using 2 pediatric surgical procedures as a test model.

Methods: A literature review was undertaken of postoperative complications following pediatric inguinal hernia repair and intestinal atresia repair. Relevant studies were included, and incidence rates and durations of all key complications were identified. Using existing disability weights of equivalent health states to the complications, we estimated the burden in DALYs of each complication. These estimates were combined into a unitary procedure-specific complication burden score.

Results: The key complications contributing to the postoperative burden following inguinal hernia repair were recurrence (0.016 DALYs), hydrocele (0.010), metachronous hernia (0.014) and port-site hernia (0.012). In the case of intestinal atresia repair, death (6.278), reoperation (12.100), stenosis (5.025) and anastomotic stricture (5.327) accounted for most of the postoperative DALYs. The complication burden score was 0.06 DALYs for inguinal hernia and 36.86 for intestinal atresia repair.

Conclusion: As a proof of concept, this study supports the feasibility of using DALYs to derive a complication burden score following surgical intervention, and to our knowledge it represents the first application of burden of disease metrics to postoperative adverse outcomes. Future studies should focus on deriving de novo disability weights for common postoperative complications and adverse outcomes.

Contexte : La comparaison des issues indésirables découlant d'interventions chirurgicales de substitution est complexe, tant pour les patients que pour les fournisseurs de soins. Partout au monde, les années de vie ajustées en fonction de l'incapacité (AVAI) sont utilisées comme indicateur quantitatif du fardeau de la maladie. Or, les AVAI n'ont jamais été appliquées au fardeau des complications postopératoires. La présente étude porte sur la faisabilité et l'utilité du recours aux AVAI pour mesurer le fardeau des complications postopératoires. Elle se sert de 2 interventions chirurgicales pédiatriques comme modèles.

Méthodes : Nous avons mené une revue de la littérature sur les complications postopératoires suivant une réparation de hernie inguinale et une correction d'atrésie intestinale chez des populations pédiatriques. Nous avons retenu les études pertinentes et dégagé le taux d'incidence ainsi que la durée des principales complications. Nous nous sommes également servis du fardeau pondéré de l'incapacité liée à un trouble de santé équivalent à chacune des complications pour estimer le fardeau, en AVAI, des complications. Les estimations ont ensuite été combinées pour obtenir un score unitaire correspondant au fardeau des complications associées à chaque intervention.

Résultats : Les principales complications contribuant au fardeau postopératoire associé à la réparation de hernie inguinale étaient la récurrence (0,016 AVAI), l'hydrocèle (0,010 AVAI), la hernie métachrone (0,014 AVAI) et la hernie au site de laparoscopie (0,012). En ce qui a trait à la correction d'atrésie intestinale, le décès (6,278 AVAI), la réopération (12,100 AVAI), la sténose (5,025 AVAI) et le rétrécissement anastomotique (5,327 AVAI) étaient à l'origine de la plupart des AVAI postopératoires. Le score du fardeau des complications était de 0,06 AVAI pour la réparation de hernie inguinale et de 36,86 AVAI pour la correction d'atrésie intestinale.

Conclusion : Cette étude, comme validation de principe, montre qu'il est possible d'utiliser les AVAI pour obtenir un score correspondant au fardeau des complications associées à une intervention chirurgicale. Elle est également la première, à notre connaissance, à appliquer un score de fardeau de la maladie aux issues postopératoires indésirables. Des études ultérieures devraient être axées sur le calcul de nouveaux fardeaux pondérés pour les complications postopératoires et les issues indésirables courantes.

Patient-centred care is described as “care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions.”¹ In surgical practice, however, surgeons often rely on their personal experiences or preferences or are governed by workplace restrictions when recommending a particular surgical option over another, while patients and their families may feel excluded, or may actually be excluded, from the decision-making process.² From a provider perspective, reliable measures of surgical risk and benefit are generally physician centred, making it difficult for surgeons to engage each other and their patients in evidence-based comparisons of alternative treatment pathways.

Lack of consensus in defining and measuring the severity of surgical outcomes using a patient-centred metric hinders reliable discussion and comparison of surgical procedures with patients and their families.³ Most complication severity scores are based on the validated Clavien–Dindo system created in 1992 and updated in 2004, which serves to objectively classify complications on the basis of the severity of the therapeutic intervention required to address them.^{4,5} Composite scores have been devised to quantify all complications experienced by patients postoperatively.^{6,7} However, these scores are still built on care-centred complication criteria rather than on the actual patient burden accrued from experiencing these complications. For these reasons, quantifiable information on quality of life after surgery that can be used in the decision-making process among surgeons, and between surgeons and their patients, remains elusive.

An example of a utility measurement is the disability-adjusted life year (DALY), a metric combining morbidity and mortality to quantify the burden of disease. It is the main metric used in assessment, intervention, evaluation and advocacy for health care policy in low- and middle-income countries.^{8–11} The DALY is expressed as the cumulative number of years lost from premature mortality and the loss of health experienced by living a certain number of years with a disability.^{8,12,13} The basic formula is that DALY equals YLL plus YLD, where YLL is the number of years lost as a result of the health state and YLD is the number of years of life with disability as a result of the health state. YLL can be calculated by multiplying the number of deaths by the standard life expectancy at the age of death (in yr). YLD can be calculated by multiplying the incident rate of any complication by its disability weight (DW) and the average duration of the complication (in yr).

One important component of the YLD in the estimation of morbidity is the DW, which reflects the severity of the disease; it is measured on a scale of 0 (perfect health) to 1 (equivalent to death).¹⁴ Various health valuation techniques can be used to generate DWs, and individual weights of health states can be combined to yield unitary weights for any given disease.¹⁵ Similarly, we aimed to

derive a unitary patient-centred complication score by combining the various burden values (in DALYs) of individual adverse events expected after any surgical procedure. This study is a pilot exercise, focusing on the feasibility of using utility weights in measuring and comparing the burden experienced by patients when undergoing various surgical interventions. We use 2 surgical conditions as models for this study: pediatric inguinal hernia, the most common elective condition in pediatric surgery, and intestinal atresia, a diagnosis that carries a substantial risk of mortality and morbidity.

METHODS

Derivation of frequency and duration of complications from the literature

To identify the key complications that patients experience after undergoing the 2 index procedures, we undertook a nonsystematic review of the literature to identify for each condition several exemplar studies that included the desired information. The search strategy, detailed in Figure 1 and Figure 2, was developed in collaboration with a senior hospital librarian (E.G.). The MEDLINE (Ovid) database was consulted for relevant articles discussing the complications associated with inguinal hernia and intestinal atresia repair in children younger than 18 years. Studies published between January 2008 and May 2018 (for inguinal hernia) and between January 2008 and August 2018 (for intestinal atresia) were included. The search was restricted to studies from high-income countries published in English and French. Case reports and animal studies were excluded. The search strategy used variations in text words found in the title, abstract or keyword fields and in relevant subject headings to retrieve articles pertaining to inguinal hernia, herniorrhaphy, hernioplasty or intestinal atresia repair and various documented postoperative adverse events, recurrence, readmission or death in children (Appendix 1, Supplemental Table S1 and Table S2, available at canjsurg.ca/004819-a1). The goal of the search was to identify publications listing severe or common postoperative complications pertaining to inguinal hernia and intestinal atresia repair in children.

Eligibility of the articles was determined on the basis of the quality of the article, the inclusion of complications and the target population. Articles deemed to be of adequate quality needed to show that the investigators appropriately monitored and listed at least 2 complications. Complications that were very rare or short term in nature were excluded because of their negligible impact on DALY values. Articles with inadequate follow-up were also excluded. Newborns of low birth weight and newborns born prematurely were excluded from the study because these infants have several other comorbidities and their inclusion would inflate the DALY values in a manner not

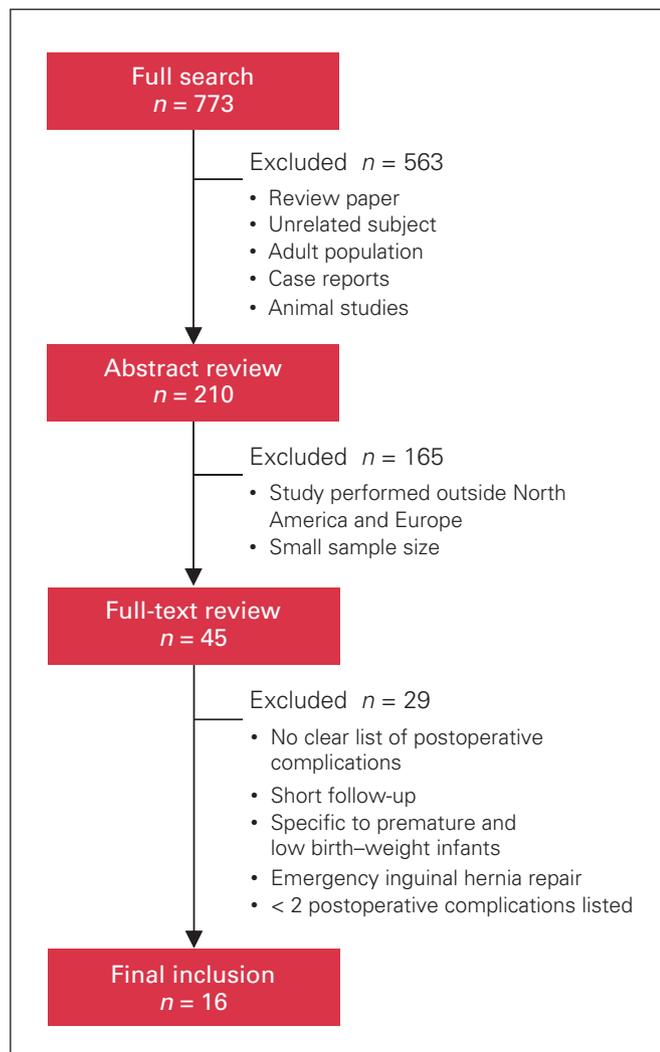


Fig. 1. Flowchart outlining the selection process of the articles on inguinal hernia repair.

applicable to the rest of the study population. For example, a premature newborn with an inguinal hernia is at higher risk of respiratory complications that are not necessarily related to the hernia.

After duplicates were removed from the search results, an independent reviewer (S.M.) performed a first screen on the basis of titles and abstracts alone. Any ambiguity was clarified by the senior author (D.P.). Subsequently, the same reviewer (S.M.) performed full-text screening on the basis of the above-mentioned eligibility criteria. The various incidence rates of all postoperative complications reported in the included studies were extracted.

DALY calculations

The primary outcome was the incidence rate of various postoperative complications following the 2 index procedures. From the incidence rate, the total DALY-based

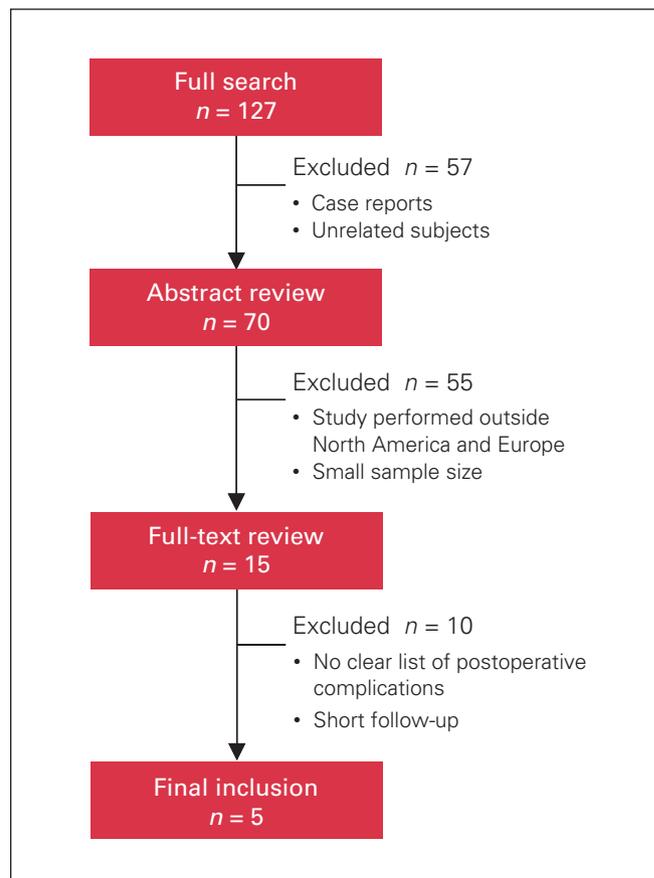


Fig. 2. Flowchart outlining the selection process of the articles on intestinal atresia repair.

complication burden score was calculated for each postoperative complication (see Appendix 1, Supplemental Box S1 for the formula).

In this study, we assumed a life expectancy at birth similar to that used in the latest Global Burden of Disease study (86 yr for both males and females).¹⁶ The DWs for the complications were extracted from the Institute for Health Metrics and Evaluation Global Burden of Disease database,¹⁷ the Korean burden of disease study¹⁸ and other literature sources.¹⁹ To date, DWs have not been specifically generated for postoperative complications. Therefore, the closest existing health-state DWs were identified and used as surrogate severity markers in this study to estimate the burden in DALYs for each respective postoperative complication. For instance, a DW of 0.006 was used for wound infection, based on the Institute for Health Metrics and Evaluation health state “infectious disease, acute episode, mild,” with the lay description “has a low fever and mild discomfort, but no difficulty with daily activities.”¹⁷

In the case of postoperative states without obvious surrogate DWs, we extrapolated DW values by expert consensus between 2 pediatric surgeons (R.B., D.P.). For instance, given that wound hematoma produces a

burden on patient’s postoperative well-being similar to that produced by mild wound infection, the DW for these conditions was assumed to be similar to that for wound infection. Recurrence, metachronous hernia, port-site hernia and postoperative hydrocele requiring reoperation were assumed to have the same DWs as the original inguinal hernia. Because injury to the vas deferens leads to a quantifiable decrease in fertility, a fraction of the DW for primary infertility was used in this situation. For intestinal atresia repair, the DW of short bowel obstruction was assumed to be similar to that of protein-energy malnutrition, and the DW of anastomotic leak was assumed to be similar to that of the sepsis, which it typically results in. The DW for any fatal complication in the absence of reoperation (such as necrotizing enterocolitis, intestinal necrosis and anastomotic stricture) was assumed to be the same as that of the original condition. This key limitation is further elaborated in the Discussion section. The duration of each complication was based on expert pediatric surgeons’ opinions (R.B., D.P.).

Given that the studies included in the analysis used different measures of central tendency to report the age of the patients (mean, median and range), the weighted average could not be used to calculate the duration of a permanent disability (unless treated). As patients ranged in age from 0 to 17 years, the midpoint between these 2 extremes was assumed to be the age of onset of the complications. The duration of the complication was therefore calculated as the standard life expectancy at age of death (yr) minus age of onset of the complication (yr) (e.g., 86 yr minus 8.5 yr equals 77.5 yr). This standard

methodology reflects the reality that until a nonresolving complication is addressed (e.g., reoperating for recurrent inguinal hernia or operating on a postoperative bowel obstruction) or in the absence of such a correction, in theory the disability persists until death.

RESULTS

Inguinal hernia repair

The initial search strategy yielded 773 articles on inguinal hernia repair. The title and abstract screen eliminated 728 articles, leaving 45 articles for full-text review. Small series (fewer than 80 patients) were excluded. Sixteen published studies met the inclusion criteria and were selected for analysis^{20–35} (Fig. 1).

Table 1 outlines the study type, duration of follow-up, number of hernia repairs and patient characteristics reported in the selected articles on inguinal hernia repair. Table 2 provides the common postoperative complications associated with inguinal hernia repairs, the individual incidence rate for each complication reported in each study and the overall incidence rate for each complication calculated using a weighted average.

Table 3 outlines the overall incidence rate and duration for each complication, the surrogate DW for each complication and the source from which that DW was retrieved. Multiplying the incidence rate, duration and DW results in the DALY-based burden of each complication, while the sum of all these burden values yields the complication burden score (CBS) for inguinal hernia repair.

Table 1. Study and patient characteristics for the included studies on inguinal hernia repair

Study	Study type	Median or mean follow-up, * mo	No. of patients	% male	% female	No. of hernias	Median or mean patient age*
Bruzoni et al. ²⁰	Retrospective review	24	166	67	33	216	29.5 mo
Giseke et al. ²¹	Retrospective review	> 6	385	54	46	525	Range 0.13–16.8 yr
Baird et al. ²²	Retrospective review	> 12	170	—	—	170	7.32 mo
Choi et al. ²³	Retrospective review	46	380	79	21	380	4.5 mo
Marte et al. ²⁸	Retrospective review	24	224	78	22	248	5 yr
Turial et al. ³⁴	Prospective review	42	100	78	22	140	2.3 yr
Sneider et al. ³²	Retrospective review	Range 7–45	116	69	31	165	Range 3 wk–14 yr
Steven et al. ³³	Retrospective review	3.86	254	—	—	254	0.54 yr
Koivusalo et al. ³⁵	Prospective single-blinded RCT	2	89	—	—	89	Range 4 mo–16 yr
Niyogi et al. ³⁰	Retrospective review	8	222	56	44	222	Range < 1–15 yr
Pogorelic et al. ³¹	Retrospective review	168	6826	70	30	6826	3.5 yr
Geiger et al. ²⁶	Retrospective review	38	123	63	37	123	—
Dutta and Albanese ²⁴	Prospective review	—	187	—	—	275	—
Esposito et al. ²⁵	Retrospective review	—	1300	—	—	1300	18 mo
Libri et al. ²⁷	Retrospective review	14.8	123	—	—	123	—
McClain et al. ²⁹	Prospective review	10.7	495	—	—	710	29.2 mo

RCT = randomized controlled trial.
 *Unless indicated otherwise.

Table 2. Common postoperative complications associated with inguinal hernia repair in the included studies

Study	Recur. (%)	Wound infection, %	Testic. atrophy, %	Hydrocele, %	Hematoma, %	Testic. ascent, %	Granuloma, %	Metach. hernia, %	Port-site hernia, %	Vas deferens injury, %	Nausea or vomiting or both, %	Nuck's cyst, %
Bruzoni et al. ²⁰	1.8	—	0.0	1.4	0.5	—	—	—	—	—	—	—
Giseke et al. ²¹	1.0	0.2	0.0	1.3	1.3	0.0	—	—	—	—	24.3	0.2
Baird et al. ²²	4.1	1.8	0.0	2.9	—	0.6	—	—	—	0.6	—	—
Choi et al. ²³	1.8	1.6	0.3	1.3	—	0.3	—	0	1.6	—	—	—
Marte et al. ²⁹	2.0	—	—	—	0.4	—	—	—	—	—	—	—
Turial et al. ³⁴	1.4	—	0.0	—	—	—	—	—	—	—	—	—
Sneider et al. ³²	1.8	0.6	—	—	—	—	—	—	—	—	—	—
Steven et al. ³³	3.5	0.4	0.4	—	—	0.8	—	2.8	1.2	—	—	—
Koivusalo et al. ³⁵	3.4	—	0.0	—	—	—	—	5.6	—	—	—	—
Niyogi et al. ³⁰	5.0	2.2	0.9	—	—	—	—	—	—	—	—	—
Pogorelic et al. ³¹	2.2	0.1	0.03	—	0.1	—	—	—	—	—	—	—
Geiger et al. ²⁶	6.5	1.6	—	—	—	—	—	—	—	—	—	—
Dutta and Albanese ²⁴	1.4	1.4	—	0.7	2.2	—	0.7	—	—	—	—	—
Esposito et al. ²⁵	0.4	0.2	—	—	—	—	1.4	—	—	—	—	—
Libri et al. ²⁷	—	0.8	—	1.6	—	—	—	—	—	—	—	—
McClain et al. ²⁹	0.6	1.3	—	0.6	—	—	1.1	—	—	—	—	—
Total rate of each complication (weighted average)	1.9	0.4	0.08	1.2	0.3	0.3	1.2	3.5	1.4	0.6	24.3	0.2

Metach. = metachronous; Recur. = recurrence; Testic. = testicular.

Table 3. DALY-based complication burden score for inguinal hernia repair

Complication	Closest similar known condition	YLD			DALY-based CBS, yr
		Incidence, %	Duration, yr	Disability weight*	
Recurrence	Inguinal hernia	0.019	77.00	0.011	0.016
Wound infection	Wound infection	0.004	0.04	0.006	0.000
Testicular atrophy	Infertility	0.001	77.00	0.008	0.000
Hydrocele	Inguinal hernia	0.012	77.00	0.011	0.010
Hematoma	Wound infection	0.003	0.04	0.006	0.000
Testicular ascent	Infertility	0.003	77.00	0.008	0.002
Granuloma	Wound infection	0.012	0.04	0.006	0.000
Metachronous hernia	Inguinal hernia	0.017	77.00	0.011	0.014
Port-site hernia	Inguinal hernia	0.014	77.00	0.011	0.012
Vas deferens injury	Infertility	0.006	77.00	0.008	0.004
Nausea or vomiting or both	Nausea or vomiting or both	0.243	0.02	0.011	0.000
Nuck's cyst	Inguinal hernia	0.002	77.00	0.011	0.002
Total DALY-based CBS					0.060

CBS = complication burden score; DALY = disability-adjusted life year; YLD = years of life with disability.
*Disability weights were extracted from the Institute for Health Metrics and Evaluation Global Burden of Disease database.¹⁷

Table 4. Study and patient characteristics for the included studies on intestinal atresia repair

Study	Study type	Mean follow-up	No. of patients	% male	% female	Gestational age, wk
Nusinovich et al. ³⁷	Retrospective review	3 yr	118	41	59	< 37–40
Piper et al. ³⁸	Retrospective review	2 yr	132	48	52	31.9–39.4
Stollman et al. ³⁹	Retrospective review	—	114	58	42	< 37–40
Zani et al. ⁴⁰	Retrospective review	6.5 mo	92	66	34	33.2–39.6
Burjonrappa et al. ³⁶	Retrospective review	1.43 yr	130	51	49	36–37

F = female; M = male.

Table 5. Common postoperative complications associated with intestinal atresia repair in included studies

Study	Death, %	SBS, %	Reop., %	Sepsis, %	Anast. leak, %	Wound infection, %	NE, %	NB, %	SBO, %	Stenosis, %	Anast. stricture, %	IH, %	B ₁₂ defic., %
Nusinovich et al. ³⁷	10.2	—	—	—	—	—	—	—	—	—	—	—	—
Piper et al. ³⁸	7	9.8	17	—	—	—	—	—	—	—	—	—	—
Stollman et al. ³⁹	11	15	—	8	7	3.5	0.009	0.03	12.3	6.2	—	3.5	1.8
Zani et al. ⁴⁰	2.2	—	4.4	—	0	—	—	—	4.4	—	6.5	—	—
Burjonrappa et al. ³⁶	5.4	—	20	—	—	—	—	—	12.3	—	—	—	—
Total rate of each complication (weighted average)	7.3	12.2	14.8	8	3.9	3.5	0.009	0.03	10.1	6.2	6.5	3.5	1.8

Anast. = anastomotic; defic. = deficiency; IH = incisional hernia; infect. = infection; NE = necrotizing enterocolitis; NB = necrotizing bowel; Reop = reoperation; SBO = small bowel obstruction; SBS = short bowel syndrome.

The complications accounting for the largest residual DALY value in inguinal hernia repair were recurrence (0.016), hydrocele (0.010), metachronous hernia (0.014) and port-site hernia (for laparoscopic repairs) (0.012). The total DALY-based CBS for pediatric inguinal hernia repair was 0.060, significantly lower than the actual burden of an unoperated inguinal hernia, 0.77 DALY (77 yr × 0.01).¹⁷ No comparison was made in this pilot study between open and laparoscopic inguinal hernia repair in children.

Intestinal atresia repair

The search strategy for intestinal atresia repair initially yielded 125 publications, with an additional 2 publications identified through snowballing. After the title and abstract screen, 112 papers were excluded, leaving 15 articles for full-text review. Five of these were retained for analysis^{36–40} (Fig. 2). Table 4 outlines the study type, duration of follow-up, and patient characteristics for the included studies; Table 5 presents the incidence rate, calculated as a weighted average, for each postoperative complication in these studies. The weighted average was calculated for a total incidence

rate for each complication. Reoperation had the highest incidence rate (14.8%), followed by short bowel syndrome (12.2%) and small bowel obstruction (10.1%).

Table 6 lists the average incidence rate for complications following intestinal atresia repair, the approximate duration of each complication, the corresponding DW and the source from which the DW was retrieved. The duration of each complication, its DALY-based burden and the final CBS were calculated in a fashion similar to that for inguinal hernia repair.

The postoperative complications accounting for the largest DALY-based burden after intestinal atresia repair were death (6.278), reoperation (12.100), stenosis (5.025) and anastomotic stricture (5.327). The CBS was 36.86 DALYs, including 30.58 healthy life-years lost because of living in a less-than-optimal health state (YLDs) and 6.278 healthy life-years lost because of premature death (YLLs)¹² (Table 6).

DISCUSSION

Patient-centred decision-making in surgery requires that a provider be willing and available to take time with patients and their families to explain the various possible

Table 6. DALY- based complication burden score for intestinal atresia repair

	Closest similar known condition	YLL		YLD			Reference for disability weight	DALY-based CBS
		Incidence, %	Life expectancy, yr	Incidence, %	Duration, yr	Disability weight		
Death		0.073	86	—	—	—		6.278
Short bowel syndrome	Malnutrition	—	—	0.1223	86.0	0.362	Ock et al. ¹⁸	3.807
Reoperation	Intestinal atresia	—	—	0.1481	86.0	0.95	Poenaru et al. ¹⁹	12.100
Sepsis	Sepsis	—	—	0.0800	86.0	0.133	Institute of Health Metrics and Evaluation ¹⁷	0.915
Anastomotic leak	Sepsis	—	—	0.0387	86.0	0.133	Institute of Health Metrics and Evaluation ¹⁷	0.443
Wound infection	Wound infection	—	—	0.0350	0.0	0.006	Institute of Health Metrics and Evaluation ¹⁷	0.000
Necrotizing enterocolitis	Intestinal atresia	—	—	0.0001	86.0	0.95	Poenaru et al. ¹⁸	0.007
Necrotizing bowel	Intestinal atresia	—	—	0.0003	86.0	0.95	Poenaru et al. ¹⁹	0.021
Small bowel obstruction	Small bowel obstruction	—	—	0.1012	86.0	0.324	Institute of Health Metrics and Evaluation ¹⁷	2.820
Stenosis	Intestinal atresia	—	—	0.0615	86.0	0.95	Poenaru et al. ¹⁹	5.025
Anastomotic stricture	Intestinal atresia	—	—	0.0652	86.0	0.95	Poenaru et al. ¹⁹	5.327
Incisional hernia	Inguinal hernia	—	—	0.0350	86.0	0.011	Institute of Health Metrics and Evaluation ¹⁷	0.033
B ₁₂ deficiency	Anemia	—	—	0.0175	86.0	0.052	Institute of Health Metrics and Evaluation ¹⁷	0.078
Total DALY-based CBS								36.85

CBS = complication burden score; DALY = disability-adjusted life year; YLD = years of life with disability.

therapeutic choices. This can be greatly facilitated by a tool enabling patients to understand and compare the burden of disease, interventions and potential adverse events of various treatment options in terms of their quality of life. Although condition-specific decision aids have been devised for this purpose, these tools have largely focused on simply translating medical information into simpler language that makes the latest evidence in practice more accessible for patients. Although this is helpful, there still exists a failure to acknowledge patients' opinions on the impact of the presented options on quality of life. There is a need to combine the burden and frequency of individual complications into a unitary score, which can allow direct comparisons between alternative procedures (or between surgical interventions and conservative management) in terms of their direct adverse impact on patient well-being.

The goal of this pilot project was to establish the feasibility of a DALY-based complication burden score in surgery. For this purpose, we chose the treatment of 2 key pediatric surgical conditions, inguinal hernia and intestinal atresia, because these conditions represent diseases with varying health burdens on the patient and thus would enable us to test the applicability of the score to

conditions across the disease severity spectrum. The DW, a factor anchored on a scale from 0 (perfect health) to 1 (equivalent to death), has been previously derived for both inguinal hernia and intestinal atresia: specifically 0.011 for the former and 0.95 for the latter.^{17,19}

As a proof of concept, using existing DWs from the literature that served as surrogates for postoperative adverse outcome states, we estimated a composite score representing the complication burden. The CBS serves as a measure of mortality and morbidity that quantifies the burden accrued by a patient undergoing a specific operation for a surgical disease and develops the possible complications associated with that specific procedure. In the current study the CBS for inguinal hernia repair was 0.060 DALYs, meaning that a child who underwent an operation for this condition would lose 0.06 potential years of healthy life because of potential adverse events following the procedure. The equivalent CBS for intestinal atresia repair was much higher (36.86 DALYs), representing an average of multiple possible complications and reflecting the severity of potential complications and the young age of patients. The average patient is expected to lose 36.86 years of healthy survival as a result of the repair of an otherwise fatal intestinal atresia.

When the CBS of each procedure is compared with the actual burden of the conditions themselves, the utility of surgical intervention becomes apparent. Considering a life expectancy of 77 years for a child with a newly diagnosed inguinal hernia, which has a disability weight of 0.1 DALYs, the lifelong burden in this child averted by surgery would therefore be approximately 7.7 DALYs (i.e., over 10 times the residual burden of the procedure). In the case of intestinal atresia repair, the residual burden of 36.86 DALYs also compares very favourably with 81.7 DALYs, the equivalent of a condition with a virtually universally fatal outcome.

Although the CBS appeared to yield predictable results in both conditions, its estimation was much more precise for intestinal atresia than for inguinal hernia. The reason for this was that complications following inguinal hernia repair are infrequent and generally mild, all situated in the bottom tenth of the disability weight scale, where the standard error is significant. This finding suggests that a DALY-based CBS is better suited to more morbid conditions and interventions, while milder conditions with safer treatment may need to be measured on a modified scale that is better able to discriminate lower DW values.

While demonstrating the feasibility of a generic utility-based score, the study identified the limitation of DWs and DALYs particularly for less severe surgical conditions. Hence the next step in this inquiry would be not only the *de novo* generation of health utilities for postoperative complications but also potentially departing from standard DWs to generating other, better suited health utility scores. These scores would then require extensive clinical validation, testing both for their fidelity and their ability to enhance the surgical decision-making process, and ultimately to improve patient outcomes and satisfaction. The CBS specifically reflects the burden of postoperative adverse events on the patient; it does not consider the burden of simply undergoing surgery on both the patient and the caregivers. This much broader exploration is necessary and constitutes another suitable future direction for investigation.

Limitations

Although the purpose of the study was to address the feasibility of using DALYs to quantify the burden of postoperative outcomes, there are several limitations to our methodology. First, no disability weights have been derived to date for postoperative adverse events. Therefore, the weights we used to estimate surgical complication DALYs were extracted from existing burden of disease data, where they are used to quantify general health states rather than postoperative complications. Moreover, as already highlighted in the Methods, we

made assumptions to use other existing DWs as surrogates for postoperative adverse outcomes. Also, the applicability of many DW values is limited by the geographic and sociocultural robustness of their original derivation, as well as their validity over a wide spectrum of health state severity levels and age brackets. It is clear that the only solution to avoiding these significant assumptions will be a *de novo* estimation of either DWs or other equivalent health state utilities specifically for postoperative adverse events.

Second, as the complication burden score is DALY based, it inherits all the limitations of the DALY metric. DALYs are built on DWs, which are generated using a variety of health valuation exercises completed by the general public.¹⁵ Therefore, DALYs are limited by their subjectivity on the basis of participant selection for completion of these exercises. Moreover, despite the broad global adoption and use of DALYs, there are multiple assumptions and controversies in the weight estimates, universal versus country-specific life expectancies, and the use of age weighting and discounting.⁴¹ DALYs, along with other population health utilities, are approximations, averages of multiple individual utilities, which can vary considerably in severity by age or other factors.

Third, in this pilot study we assumed that the overall complication burden after a surgical intervention is the simple sum of the burden of each adverse event. This is probably not true, as demonstrated by Slankamenac and colleagues in their Comprehensive Complex Index.⁴² Similarly to their validation work, the individual factors in the CBS will need to be modulated to reflect their interactive impact on a patient experiencing more than 1 complication at any given time after a procedure.

Finally, it must again be stated that the complication frequency data were not generated through a systematic review but rather through an *ad hoc* sampling of the literature to identify exemplar studies.

CONCLUSION

Despite its limitations, the current pilot study adequately demonstrates the feasibility of a health utility-based complication burden score, representing the first application of burden of disease metrics to postoperative adverse events. The score reinforces a patient-centred perspective on surgical morbidity and potentially allows for outcomes-driven comparisons between alternative surgical procedures for a given condition. In clinical practice, such a score could be used directly by surgical providers in making patient-centred decisions, while for patients it could be integrated within a decisional aid incorporating various additional patient values and priorities. A patient-centred, unitary complication burden score can be created for any surgical

specialty or subspecialty, as long as it factors in the most common and important adverse events encountered after a chosen set of interventions. It is therefore potentially applicable to any setting where surgeons and patients need to decide together on the best way to treat a surgical condition.

Affiliations: From the Harvey E. Beardmore Division of Pediatric Surgery, Montreal Children's Hospital, McGill University Health Centre, Montréal, Que. (Mohtashami, Safa, Guadagno, Poenaru); and the Department of Surgery, British Columbia Children's Hospital, University of British Columbia, Vancouver, B.C. (Baird).

Competing interests: None declared.

Contributors: S. Mohtashami, E. Guadagno and D. Poenaru designed the study. S. Mohtashami and E. Guadagno acquired the data, which all authors analyzed. S. Mohtashami, N. Safa and E. Guadagno wrote the article, which all authors critically revised. All authors gave final approval of the version to be published.

References

- Institute of Medicine Committee on Quality of Health Care in America. *Crossing the quality chasm: a new health system for the 21st century*. Washington (DC): National Academies Press; 2001.
- Barry MJ, Edgman-Levitan S. Shared decision making — the pinnacle of patient-centered care. *N Engl J Med* 2012;366:780-1.
- Horton R. Surgical research or comic opera: questions, but few answers. *Lancet* 1996;347:984-5.
- Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;240:205-13.
- Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg* 2009;250:187-96.
- Slankamenac K, Nederlof N, Pessaux P, et al. The comprehensive complication index: a novel and more sensitive endpoint for assessing outcome and reducing sample size in randomized controlled trials. *Ann Surg* 2014;260:757-62, discussion 762-3.
- Strasberg SM, Hall BL. Postoperative morbidity index: a quantitative measure of severity of postoperative complications. *J Am Coll Surg* 2011;213:616-26.
- World Health Organization. *Metrics: disability-adjusted life year (DALY)*. Geneva: World Health Organization; 2014.
- GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016;388:1545-602.
- Murray CJL, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2197-223.
- Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015;386:743-800.
- Devleeschauwer B, Havelaar AH, Maertens de Noordhout C, et al. Calculating disability-adjusted life years to quantify burden of disease. *Int J Public Health* 2014;59:565-9.
- Murray CJ. Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bull World Health Organ* 1994;72:429-45.
- Haagsma JA, Polinder S, Cassini A, et al. Review of disability weight studies: comparison of methodological choices and values. *Popul Health Metr* 2014;12:20.
- Rehm J, Frick U. Valuation of health states in the US study to establish disability weights: lessons from the literature. *Int J Methods Psychiatr Res* 2010;19:18-33.
- Murray CJL, Ezzati M, Flaxman AD, et al. GBD 2010: design, definitions, and metrics. *Lancet* 2012;380:2063-6.
- Institute of Health Metrics and Evaluation. *Global Burden of Disease Study 2016 (GBD 2016) disability weights*. Seattle (WA): Global Health Data Exchange; 2016. Available: <http://ghdx.healthdata.org/record/global-burden-disease-study-2016-gbd-2016-disability-weights> (accessed 27 Jan. 2019)
- Ock M, Lee JY, Oh IH, et al. Disability weights measurement for 228 causes of disease in the Korean Burden of Disease Study 2012. *J Korean Med Sci* 2016;31(Suppl 2):S129-38.
- Poenaru D, Pemberton J, Frankfurter C, et al. Establishing disability weights for congenital pediatric surgical conditions: a multi-modal approach. *Popul Health Metr* 2017;15:8.
- Bruzoni M, Jaramillo JD, Kastenber ZJ, et al. Long-term follow-up of laparoscopic transcuteaneous inguinal herniorrhaphy with high transfixation suture ligature of the hernia sac. *J Pediatr Surg* 2015;50:1767-71.
- Giseke S, Glass M, Tapadar P, et al. A true laparoscopic herniotomy in children: evaluation of long-term outcome. *J Laparoendosc Adv Surg Tech A* 2010;20:191-4.
- Baird R, Gholoum S, Laberge J-M, et al. Prematurity, not age at operation or incarceration, impacts complication rates of inguinal hernia repair. *J Pediatr Surg* 2011;46:908-11.
- Choi W, Hall NJ, Garriboli M, et al. Outcomes following laparoscopic inguinal hernia repair in infants compared with older children. *Pediatr Surg Int* 2012;28:1165-9.
- Dutta S, Albanese C. Transcuteaneous laparoscopic hernia repair in children: a prospective review of 275 hernia repairs with minimum 2-year follow-up. *Surg Endosc* 2009;23:103-7.
- Esposito C, Escolino M, Cortese G, et al. Twenty-year experience with laparoscopic inguinal hernia repair in infants and children: considerations and results on 1833 hernia repairs. *Surg Endosc* 2017;31:1461-8.
- Geiger S, Bobylev A, Schädelin S, et al. Single-center, retrospective study of the outcome of laparoscopic inguinal herniorrhaphy in children. *Medicine (Baltimore)* 2017;96:e9486.
- Libri M, Destro F, Cantone N, et al. 'Double N': evolution of the surgical technique for laparoscopic herniorrhaphy after 10-year experience in a single center. *J Laparoendosc Adv Surg Tech A* 2015;25:684-8.
- Marte A, Sabatino MD, Borrelli M, et al. Decreased recurrence rate in the laparoscopic herniorrhaphy in children: comparison between two techniques. *J Laparoendosc Adv Surg Tech A* 2009;19:259-62.
- McClain L, Streck C, Leshner A, et al. Laparoscopic needle-assisted inguinal hernia repair in 495 children. *Surg Endosc* 2015;29:781-6.
- Niyogi A, Tahim AS, Sherwood WJ, et al. A comparative study examining open inguinal herniotomy with and without hernioscopy to laparoscopic inguinal hernia repair in a pediatric population. *Pediatr Surg Int* 2010;26:387-92.
- Pogorelec Z, Rikalo M, Jukic M, et al. Modified Marcy repair for indirect inguinal hernia in children: a 24-year single-center experience of 6826 pediatric patients. *Surg Today* 2017;47:108-13.
- Sneider EB, Jones S, Danielson PD. Refinements in selection criteria for pediatric laparoscopic inguinal hernia repair. *J Laparoendosc Adv Surg Tech A* 2009;19:237-40.
- Steven M, Carson P, Bell S, et al. Simple purse string laparoscopic versus open hernia repair. *J Laparoendosc Adv Surg Tech A* 2016;26:144-7.
- Turial S, Saied A, Schier F. Microlaparoscopic hernia repair in children: initial experiences. *Surg Innov* 2011;18:368-72.
- Koivusalo AI, Korpela R, Wirtavuori K, et al. A single-blinded, randomized comparison of laparoscopic versus open hernia repair in children. *Pediatrics* 2009;123:332-7.
- Burjonrappa S, Crete E, Bouchard S. Comparative outcomes in intestinal atresia: a clinical outcome and pathophysiology analysis. *Pediatr Surg Int* 2011;27:437-42.

37. Nusinovich Y, Revenis M, Torres C. Long-term outcomes for infants with intestinal atresia studied at Children's National Medical Center. *J Pediatr Gastroenterol Nutr* 2013;57:324-9.
38. Piper HG, Alesbury J, Waterford SD, et al. Intestinal atresias: factors affecting clinical outcomes. *J Pediatr Surg* 2008;43:1244-8.
39. Stollman TH, de Blaauw I, Wijnen MH, et al. Decreased mortality but increased morbidity in neonates with jejunoileal atresia; a study of 114 cases over a 34-year period. *J Pediatr Surg* 2009;44:217-21.
40. Zani A, Yeh J-PB, King SK, et al. Duodeno-duodenostomy or duodeno-jejunostomy for duodenal atresia: is one repair better than the other? *Pediatr Surg Int* 2017;33:245-8.
41. Lopez AD, Mathers CD, Ezzati M, et al. *Global burden of disease and risk factors*. Washington (DC): The World Bank; 2006.
42. Slankamenac K, Graf R, Barkun J, et al. The comprehensive complication index: a novel continuous scale to measure surgical morbidity. *Ann Surg* 2013;258:1-7.