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Original Article

The burden of appendicitis and surgical site infection of appendectomy worldwide

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Abstract

Introduction: Appendicitis is a global abdominal disease and is often treated by appendectomy. Surgical site infection (SSI) is a common complication after an appendectomy that causes a significant burden on health systems. This study aimed to evaluate the trends and variations in the burden of appendicitis by year, region, socioeconomic status, and health expenditure and to assess associated SSI by appendicitis burden, surgical approach, and type of appendicitis.
Methodology: Data on Disability-Adjusted Life Years (DALYs) and the human development index were collected from the Global Burden of Disease (GBD) Study and the United Nations Development Programme, respectively. Studies on SSI after appendectomy using the uniform definition and published in 1990-2021 were retrieved.
Results: Between 1990 and 2019, the global age-standardized DALY rate of appendicitis decreased by 53.14%, with the highest burdens in Latin America and Africa. The burden of appendicitis was significantly negatively correlated with HDI (r = -0.743, $p<0.001$) and health expenditure (r = -0.287, $p<0.001$). Among 320 published studies on SSI after an appendectomy, 78.44% of studies did not report criteria for SSI diagnosis or adopt a uniform definition. In total, 69 studies with uniform SSI definitions were included. Studies with uniform SSI definitions were recorded poorly in regions with a heavy burden of appendicitis. The SSI of appendectomy was positively correlated with open appendectomy and complicated appendicitis.
Conclusions: Uniform SSI definition, promotion of laparoscopic technology, and establishment of SSI special management are needed to decrease the burden of SSI after an appendectomy, especially in developing countries.

Key words: Appendicitis; disability-adjusted life years; global burden of disease; surgical site infection; infection control.

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Introduction

Appendicitis is a global and common abdominal disease associated with relevant morbidity, mortality and significant health care costs [1]. A systematic review of population-based studies documented the pooled incidence of appendicitis to range from 100 to 151 cases per 100,000 person-years in Western countries, with a rising incidence trend in newly industrialized countries [2]. Appendectomy is the common treatment of choice for appendicitis and constitutes one of the most common surgical procedures globally, resulting in a significant burden on health systems [3].

Surgical site infection (SSI) is a common complication after an appendectomy, especially in complicated appendicitis. However, the WHO provided a comprehensive range of evidence-based recommendations for interventions to be applied during the pre, intra, and postoperative periods for the prevention of SSI, such as preoperative bathing and maintaining normal body temperature [4], SSIs are the most frequent health-care-associated infections in developing countries [5]. A recent meta-analysis showed an overall incidence of SSI of 7.0 per 100 appendectomies, varying from 0 to 37.4 per 100 appendectomies. This finding indicated that there is a heavy burden of SSI in some countries and regions after appendectomy [6].

This study set out to assess the trends and variations in the burden of appendicitis by year, region, socioeconomic status, and health expenditure, to investigate the status of research on SSI after appendectomy in regions with different appendicitis burdens, and to verify the correlation between surgical modalities/type of appendicitis and SSI of appendectomy among studies with standardized SSI definitions. Thereby discovering the weak regions and deficiencies in SSI surveillance and providing suggestions for SSI prevention and control strategies, except for routine SSI prevention measures.

Methodology

Data extraction

Data for this study were based on the Global Burden of Disease (GBD) 2019 study providing burden of appendicitis, the United Nations Development Programme (UNDP) providing the corresponding HDI and health expenditure data, and literature retrieval analysis for SSI after appendectomies.

The GBD study by the Institute for Health Metrics and Evaluation (IHME) aimed to quantify health burden due to diseases, risk factors, impairments, and injuries after stratification by age, sex, and location. The GBD study of 2019 provided insights into the health burden of 369 diseases and injuries in 204 regions and countries [7]. The burden of appendicitis was measured by DALYs in the GBD study of 2019. The following data regarding appendicitis burden were collected [8]: global and national DALY numbers, crude DALY rates, and age-standardized DALY rates of appendicitis from 1990 to 2019.

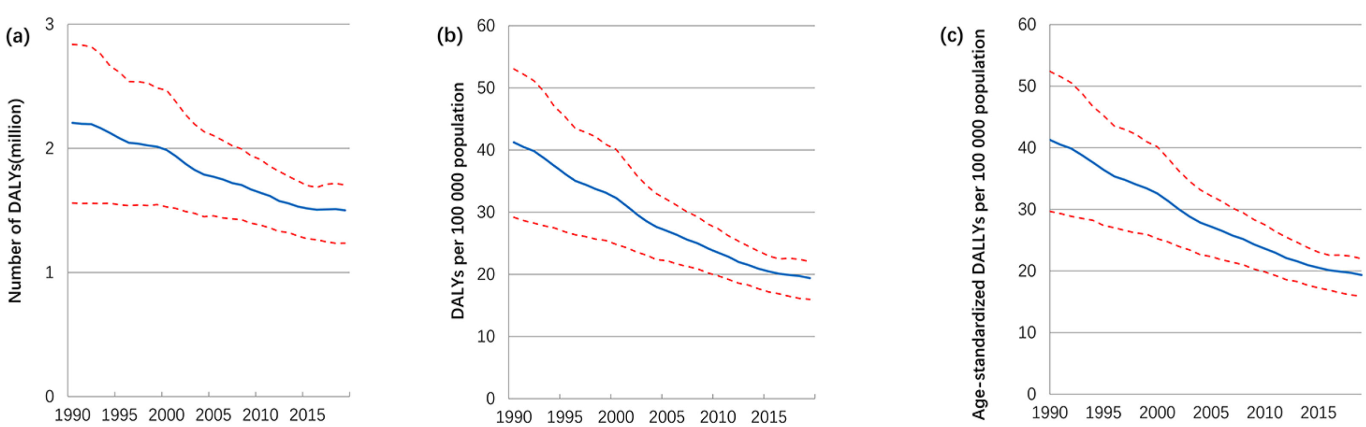
The human development index (HDI) of the UNDP is a comprehensive indicator of health, education, and living standards, ranging from 0.0 to 1.0 with a higher value indicating more advanced socioeconomic development. We obtained the HDI data and the health expenditure data of the corresponding year from the UNDP database [9]. Health expenditure is the spending on health care goods and services, expressed as a percentage of GDP. It excludes capital health expenditures, such as buildings, machinery, information technology, and stocks of vaccines for emergencies or outbreaks. Countries were grouped into four categories according to HDI values ≥ 0.80, 0.70-0.79, 0.55-0.69, and < 0.55, classified as very high, high, moderate, and low, respectively.

PubMed, Web of Science, and EMBASE were searched for studies published between 1 January 1990 and 31 December 2021 documenting the incidence of SSI after appendectomy using standardized definitions. Standardized definitions of SSI were issued by the USA National Nosocomial Infections Surveillance (NNIS) system and revised by the National Health care Safety Network (NHSN) [10]. A standardized data collection form was used by two investigators (Lin Yang and Rongshou Zheng) to extract data from the included studies independently. First author, year of publication, country, population, sample size, surgical procedure (laparoscopy or open), type of appendicitis (simple or complicated) and SSI rates were extracted.

Statistical analysis

Disparity of age-standardized DALY rates across six continents was assessed by the Kruskal–Wallis test, followed by Dunn's multiple comparison test [11]. Differences in SSI rates between open and laparoscopic appendectomy as well as simple and complicated appendicitis were assessed by the Wilcoxon test. Associations between two parameters were calculated using Spearman's rank correlation and expressed by Spearman's coefficient. Linear regression was applied to explore the associations of the age-standardized DALY rate with HDI and health expenditure and the associations of SSI with surgical modalities/type of appendicitis/HDI. A p value <0.05 indicated a statistically significant difference. Statistical analyses

Figure 1. The temporal trend of appendicitis burden over the past 30 years. (**a**) DALY numbers; (**b**) Crude DALY rates; (**c**) Age-standardized DALY rates. (Red dashed lines indicate 95% confidence interval).



were conducted using SAS 9.4. There were no ethical issues involved in this study, as the data shown here were all extracted from online websites.

Results

Appendicitis burden by year

DALY numbers due to appendicitis declined 31.82% globally, from 2.2 million in 1990 to 1.5 million in 2015, and remained relatively constant from 2015 to 2019 (Figure 1a). Similarly, DALY rates decreased by 52.92% from 41.23 per 100,000 people in 1990 to 19.41 per 100,000 people in 2019 after adjusting for population size (Figure 1b). We further controlled for age structure, gender composition, and growth of population size, which also showed a marked decrease in the age-standardized DALY rates (53.14%) from 41.29 to 19.35 per 100,000 people (Figure 1c).

Appendicitis burden by region and country in 2019

In total, 204 countries were included in the GBD 2019 study, including 54 African countries, 47 Asian countries, 44 European countries, 35 Latin American countries, 20 Oceania countries, and 4 North American countries. A significant difference in age-standardized DALY rates was found among the six continents ($H = 100.386$, $p < 0.001$). Figure 2 maps the global distribution of age-standardized DALY rates of appendicitis in 2019. The burden of appendicitis was highest in Latin America and Africa, followed by Asia, Oceania, North America, and Europe. The age-standardized DALY rates are also distributed disproportionately among countries, with the highest in Honduras and Haiti and the lowest in the Maldives (Figure 2).

Appendicitis burden by socioeconomic development and health expenditure

The age-standardized DALY rates of appendicitis in 2019 were significantly negatively correlated with the HDI (Figure 3, $r = -0.743$, $p < 0.001$). The burden of appendicitis became higher with lower levels of socioeconomic development. Moreover, health expenditure was negatively correlated with appendicitis burden (Figure 4, $r = -0.287$, $p < 0.001$).

Characteristics of studies on SSI after appendectomy

Among published studies on SSI after an appendectomy, 78.44% of the studies (251/320) did not report diagnostic criteria for SSI or did not adopt uniform criteria for SSI diagnosis (Supplementary Figure 1). Finally, 69 studies using unified diagnostic criteria for SSI were included, of which 4 were in Africa, 16 in Asia, 21 in Europe, 2 in Latin America, 24 in North America, 1 in Oceania, and 1 in multiple regions (Supplementary Table 1). The studies with consistently applied SSI definitions were recorded poorly in some regions that had a heavy burden of appendicitis, particularly in Africa and Latin American regions (Figure 2).

Figure 2. Global distribution of age-standardized DALY rates of appendicitis in 2019 and the number of studies reporting SSI after appendectomy using uniform diagnosis criteria, 1990-2021. (The size of dots indicates the number of studies).

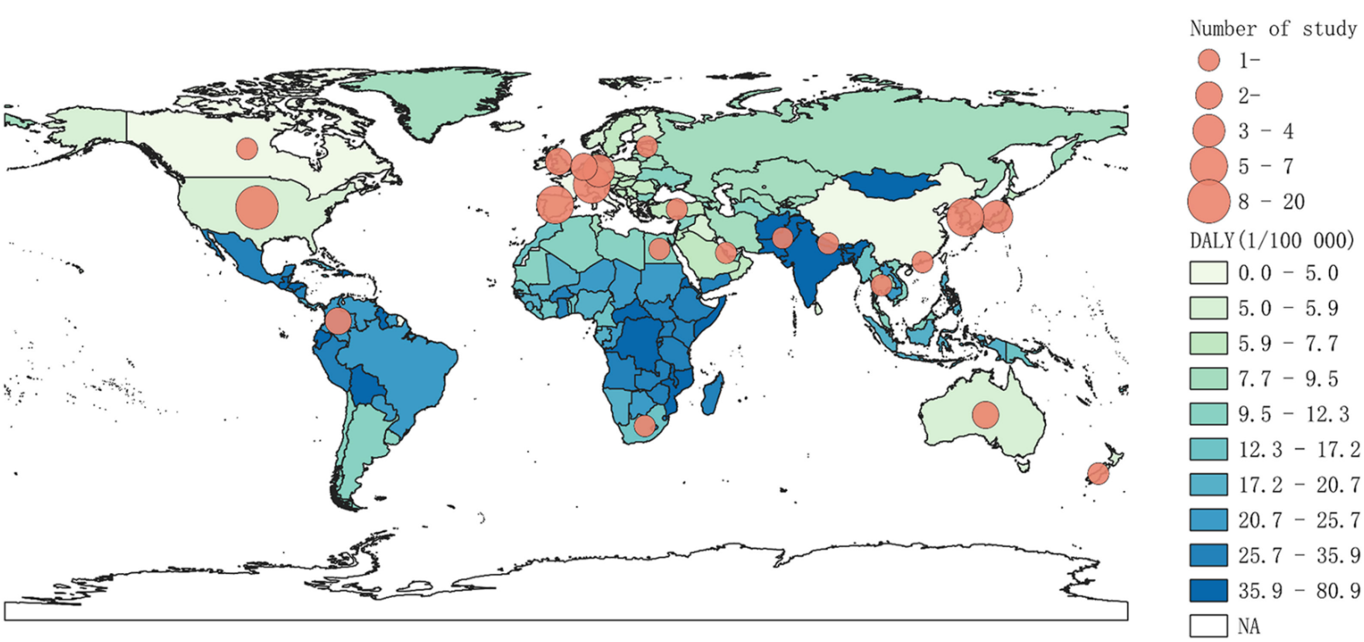


Table 1. Multivariate linear regression model of SSI after appendectomy.

Variables	Unstandardized coefficients		Standardized coefficients	T	*p* value
	β	Std. Error	β		
Proportion of complicated appendicitis*	0.117	0.025	0.606	4.703	0.000
Proportion of open appendectomy†	0.067	0.026	0.339	2.581	0.015
HDI	-0.010	0.010	-0.123	-0.923	0.363

*The proportion of complicated appendicitis in all appendicitis of each study; †The proportion of open appendectomy in all appendectomies of each study; Adjusted R-Square of the model: 0.451.

SSI after appendectomy by surgical modalities

Of the 69 included studies, 26 and 36 studies reported SSI after open and laparoscopic appendectomy, respectively. The remaining studies did not provide surgical modality information. SSI after open appendectomy was significantly higher than that after laparoscopic procedures (W = 679.000, $p < 0.001$; Supplementary Figure 2a). The linear regression analysis showed that surgical modalities had an effect on SSI after appendectomy (adjusted $R^2 = 0.058$; $p = 0.045$). SSI was positively associated with the proportion of open appendectomy (standardized β = 0.048, $p = 0.045$), Supplementary Figure 3.

SSI after appendectomy by type of appendicitis

Of the 69 included studies, 21 and 25 studies provided data on SSI of simple and complicated appendicitis, respectively. As expected, complicated appendicitis had significantly higher SSI than simple appendicitis (W = 154.000, $p < 0.001$; Supplementary Figure 2b).

The linear regression analysis showed that the proportion of complicated appendicitis also had a positive effect on SSI after appendectomy (adjusted $R^2 = 0.352$, $p < 0.001$; standardized β = 0.608, $p < 0.001$; Supplementary Figure 4).

Multiple linear regression analysis

Based upon the above findings, we included surgical modalities, type of appendicitis, and HDI as independent factors to construct a multiple linear regression model of SSI rates after appendectomy. A significant association was found between surgical modalities ($p < 0.001$) and type of appendicitis ($p = 0.015$), and the model could explain 45.1% of the SSI variance (Table 1).

Discussion

In this study, we documented the tendencies and variations in the global appendicitis burden and showed that relatively few studies with uniform SSI definitions

Figure 3. Global burden of appendicitis in terms of DALY rates by national socioeconomic development in 2019.

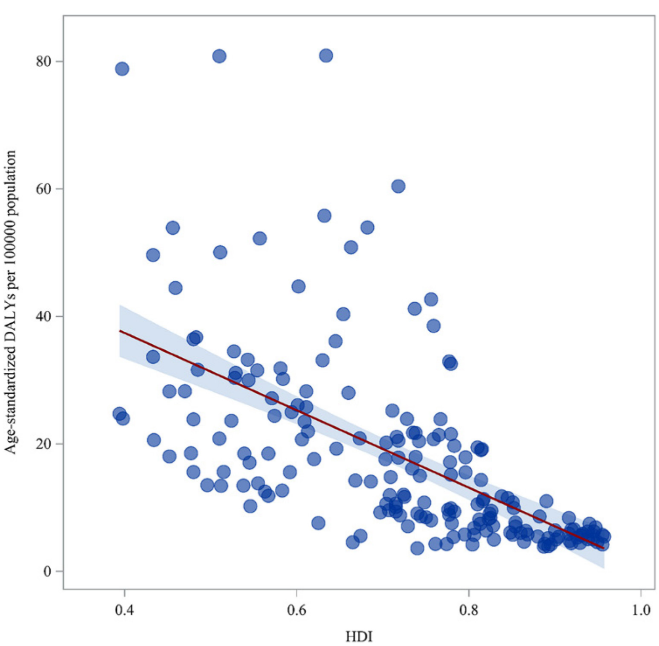
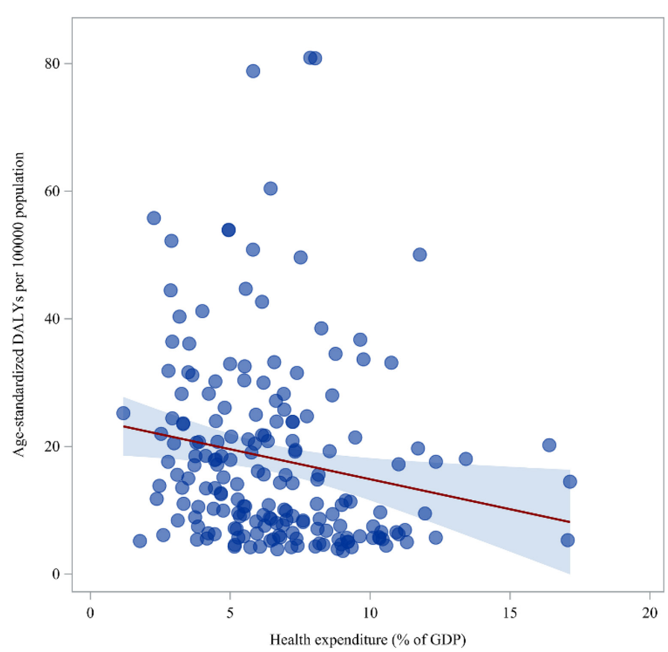


Figure 4. Global burden of appendicitis in terms of DALY rates by health expenditure in 2019 (Health expenditure is spending on healthcare goods and services, expressed as a percentage of GDP).



after appendectomy have been reported from regions with a heavy burden of appendicitis. The analysis also clearly showed that higher SSI rates were associated with open appendectomy and complicated appendicitis, which could explain over 45.1% of the variation across studies.

To our knowledge, this is the first study to evaluate both the burden of appendicitis and SSI of appendectomy worldwide on the basis of considering the SSI standard definition; such data are necessary for planning health care resource utilization. A meta-analysis of 226 studies also revealed a high incidence of SSI after appendectomy (7 per 100 appendectomies) [6]. However, uniform diagnostic criteria for SSI were not considered, and studies using a variety of different diagnostic criteria for SSI were included in that meta-analysis. Without a consistently applied definition, meaningful measurement and comparison of SSI rates are difficult to guarantee.

After accounting for the impact of population size and structure, the burden due to appendicitis has clearly decreased over the last 30 years in terms of age-standardized DALY rates. With advances in clinical diagnosis and treatment, appendicitis can be rapidly diagnosed, and its emergency can be treated promptly. As minimally invasive or laparoscopic surgery became a reality in 1983 [12], the morbidity and mortality related to appendectomy have been drastically reduced [13,14]. Rates of diagnosis and cure and life expectancy therefore may increase, which could contribute to the descending trend of appendicitis burden.

Although the overall burden of appendicitis showed a decreasing trend, it remains a matter if concern in developing countries. This study showed that the burden of appendicitis was negatively correlated with HDI and health expenditures, thus suggesting that the burdens of appendicitis are heavy in countries with low levels of socioeconomic development and fewer health expenditures. Moreover, SSI rates after appendectomy in low and middle-HDI countries are dramatically higher than rates in high-HDI countries [15]. Once surgical site infection occurs, it places a substantial burden on health care systems in terms of patient morbidity and mortality, a longer duration of hospital stay, and additional costs [4]. All the above points suggest that we should focus on reducing the disease burden and associated SSI in developing countries. In addition to routine SSI prevention measures, the following aspects should also be noted.

Uniform monitoring definition for SSI

We found that nearly 78.44% of the studies on SSI after appendectomy did not report criteria for SSI diagnosis or adopt a uniform definition. Indeed, mapping the global distribution of appendicitis in terms of DALY and the number of studies reporting SSI after appendectomy, we found a paucity of studies with consistently applied SSI definitions in regions with a heavy burden of appendicitis. In addition, we found that the burden of appendicitis is negatively correlated with HDI and health expenditures. Therefore, it is suggested that developing countries lack a uniform monitoring definition for SSI. More than 30 definitions of SSI have been used in research publications [16]. The application of a uniform definition is vital to the dependability of SSI surveillance and constitutes one of the minimal requirements for horizontal comparisons at international levels [17]. The definition of SSI from the US Centers for Disease Control (CDC) and the National Healthcare Safety Network (NHSN) is most widely used and comprehensive and can be considered a candidate for uniform definition worldwide. Standardized surveillance is an effective intervention process itself, which may effectively reduce SSI rates [18]. Surveillance using uniform SSI definitions is an effective measure for capturing a panoramic view of the global postoperative SSI of appendectomy and improving the prevention and control of surgical site infection.

Development and promotion of laparoscopic technology

However, several single, multicentre studies and meta-analyses have established correlations between open appendectomy [19-22], complex appendicitis [23-24], and increased SSI. We focused on studies with standardized SSI definitions and verified the correlation between surgical modalities/type of appendicitis and SSI of appendectomy, further suggesting that the development and promotion of laparoscopic procedures are conducive to reducing the SSI of appendicitis, especially in developing countries.

Establishment of SSI special management

Although appendicitis is a common local and global health concern, its geographical distribution in terms of disease burden is quite uneven globally. Aside from populational and genetic factors, differences at the medical level, including diagnostic modalities, medical management, and surgical practice, may partially explain the disparity in appendicitis burden observed among regions. Socioeconomic development is also associated with geographic disparity in appendicitis because more developed countries are supposed to have better health care systems and higher medical technology levels [17]. Considering area variations and resource availability, the establishment of SSI special management (including evaluation, monitoring, feedback, funding, etc.) at the national or regional level may be more effective in reducing SSI.

In addition to appendectomy, medical treatment has become a popular treatment method in recent years, especially in cases of uncomplicated acute appendicitis. The analysis of the burden of medical treatment is also an issue worth exploring. Studies have shown that the total cost of medical treatment for appendicitis ranges from \$2.7 to \$3.9 (US \$1000) [25-27]. The mean difference between medical treatment and appendectomy in total cost in US \$1000 was -\$1.31. The length of stay in medical treatment for appendicitis ranged from 37 to 156 (in Hours) [26-28], and it was longer than in appendectomy, with a mean difference of 14.32 hours [29].

The advantage of our study lies in the evaluation of both the appendicitis burden and SSI of appendectomy on a global level, discovery of possible weak regions and deficiencies in SSI surveillance, and recommendations for reducing SSI, except for routine SSI prevention measures.

However, there are some limitations regarding statistical assumptions and data sources inherent in the GBD 2019 study [7] that might have impacted the study findings. Nevertheless, the GBD 2019 study is the most standard and scientific system available for disease burden assessment. Likewise, the confounders may be inadequately controlled because SSI data are derived from published literature, and specific demographic information at the individual level is unavailable, such as age, gender, educational level, and lifestyle. Therefore, it is impossible to adjust or stratify the SSI rate according to these variables. Further research at the individual level is warranted to acquire more accurate estimations.

Conclusions

In summary, the global burden of appendicitis has continued to decrease over the past 30 years, distributed unequally, and correlated negatively with socioeconomic development and health expenditure. The burden of appendicitis in developing countries remains heavy, and there is a lack of a uniform monitoring definition for SSI. We should focus on reducing SSI and the disease burden in developing countries, including uniform monitoring definition for SSI, promotion of laparoscopic technology, and establishment of SSI special management.

Acknowledgements

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References

1. Hardin DM (1999) Acute appendicitis: review and update. Am Fam Physician 60: 2027-2034.
2. Ferris M, Quan S, Kaplan BS, Molodecky N, Ball CG, Chernoff GW, Bhala N, Ghosh S, Dixon E, Ng S, Kaplan GG (2017) The global incidence of appendicitis: a systematic review of population-based studies. Ann Surg 266: 237-241.
3. Bhangu A, Soreide K, Di Saverio S, Assarsson JH, Drake FT (2015) Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. Lancet 386: 1278-1287.
4. Allegranzi B, Bischoff P, de Jonge S, Kubilay NZ, Zayed B, Gomes SM, Abbas M, Atema JJ, Gans S, van Rijen M, Boermeester MA, Egger M, Kluytmans J, Pittet D, Solomkin JS, WHO Guidelines Development Group (2016) New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis 16: e276-e287.
5. Allegranzi B, Aiken AM, Zeynep Kubilay N, Nthumba P, Barasa J, Okumu G, Mugarura R, Elobu A, Jombwe J, Maimbo M, Musowoya J, Gayet-Ageron A, Berenholtz SM (2018) A multimodal infection control and patient safety intervention to reduce surgical site infections in Africa: a multicentre, before-after, cohort study. Lancet Infect Dis 18: 507-515.
6. Danwang C, Bigna JJ, Tochie JN, Mbonda A, Mbanga CM, Nzalie RNT, Guifo ML, Essomba A (2020) Global incidence of surgical site infection after appendectomy: a systematic review and meta-analysis. BMJ Open 10: e034266.
7. GBD Diseases and Injuries Collaborators (2020) Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease Study 2019. Lancet 396: 1204-1222.
8. Global Health Data Exchange Database (2019) GBD results tool. Available: http://ghdx.healthdata.org/gbd-results-tool. Accessed: 20 December 2021.
9. United Nations Development Programme Database (2020) Human development report: trend in the human development index, 1990-2019. Available: http://hdr.undp.org/. Accessed: 20 December 2021.
10. Horan TC, Andrus M, Dudeck MA (2008) CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control 36: 309-332.
11. Chan Y, Walmsley RP (1997) Learning and understanding the Kruskal-Wallis one-way analysis-of-variance-by-ranks test for differences among three or more independent groups. Phys Ther 77: 1755-1762.

12. Semm K (1983) Endoscopic appendectomy. Endoscopy 15: 59-64.
13. Bregendahl S, Norgaard M, Laurberg S, Jepsen P (2013) Risk of complications and 30-day mortality after laparoscopic and open appendectomy in a Danish region, 1998-2007; a population-based study of 18,426 patients. Pol Przegl Chir 85: 395-400.
14. Xiao Y, Shi G, Zhang J, Cao JG, Liu LJ, Chen TH, Li ZZ, Wang H, Zhang H, Lin ZF, Lu JH, Yang T (2015) Surgical site infection after laparoscopic and open appendectomy: a multicenter large consecutive cohort study. Surg Endosc 29: 1384-1393.
15. Foster D, Kethman W, Cai LZ, Weiser TG, Forrester JD (2018) Surgical site infections after appendectomy performed in low and middle human development-index countries: a systematic review. Surg Infect (Larchmt) 19: 237-244.
16. Leaper D, Tanner J, Kiernan M (2013) Surveillance of surgical site infection: more accurate definitions and intensive recording needed. J Hosp Infect 83: 83-86.
17. World Health Organization (2011) Report on the burden of endemic health care-associated infection worldwide. Available: http://apps.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf. Accessed: 25 November 2021.
18. Haley RW, Quade D, Freeman HE, Bennett JV (1980) The SENIC project. Study on the efficacy of nosocomial infection control (SENIC project). Summary of study design. Am J Epidemiol 111: 472-485.
19. Jaschinski T, Mosch C, Eikermann M, Neugebauer EA (2015) Laparoscopic versus open appendectomy in patients with suspected appendicitis: a systematic review of meta-analyses of randomised controlled trials. BMC Gastroenterol 15: 48.
20. Tiwari MM, Reynoso JF, Tsang AW, Oleynikov D (2011) Comparison of outcomes of laparoscopic and open appendectomy in management of uncomplicated and complicated appendicitis. Ann Surg 254: 927-932.
21. GlobalSurg C (2018) Laparoscopy in management of appendicitis in high-, middle-, and low-income countries: a multicenter, prospective, cohort study. Surg Endosc 32: 3450-3466.
22. Sahm M, Pross M, Otto R, Koch A, Gastinger I, Lippert H (2015) Clinical health service research on the surgical therapy of acute appendicitis: comparison of outcomes based on 3 German multicenter quality assurance studies over 21 years. Ann Surg 262: 338-346.
23. Boomer LA, Cooper JN, Anandalwar S, Fallon SC, Ostlie D, Leys CM, Rangel S, Mattei P, Sharp SW, St Peter SD, Rodriguez JR, Kenney B, Besner GE, Deans KJ, Minneci PC (2016) Delaying appendectomy does not lead to higher rates of surgical site infections: a multi-institutional analysis of children with appendicitis. Ann Surg 264: 164-168.
24. Somers KK, Eastwood D, Liu Y, Arca MJ (2020) Splitting hairs and challenging guidelines: Defining the role of perioperative antibiotics in pediatric appendicitis patients. J Pediatr Surg 55: 406-413.
25. Hartwich J, Luks FI, Watson-Smith D, Kurkchubasche AG, Muratore CS, Wills HE, Tracy TF, Jr. (2016) Nonoperative treatment of acute appendicitis in children: a feasibility study. J Pediatr Surg 51: 111-116.
26. Minneci PC, Mahida JB, Lodwick DL, Sulkowski JP, Nacion KM, Cooper JN, Ambeba EJ, Moss RL, Deans KJ (2016) Effectiveness of patient choice in nonoperative vs surgical management of pediatric uncomplicated acute appendicitis. JAMA surgery 151: 408-415.
27. Svensson JF, Patkova B, Almstrom M, Naji H, Hall NJ, Eaton S, Pierro A, Wester T (2015) Nonoperative treatment with antibiotics versus surgery for acute nonperforated appendicitis in children: a pilot randomized controlled trial. Ann Surg 261: 67-71.
28. Tanaka Y, Uchida H, Kawashima H, Fujiogi M, Takazawa S, Deie K, Amano H (2015) Long-term outcomes of operative versus nonoperative treatment for uncomplicated appendicitis. J Pediatr Surg 50: 1893-1897.
29. Huang L, Yin Y, Yang L, Wang C, Li Y, Zhou Z (2017) Comparison of antibiotic therapy and appendectomy for acute uncomplicated appendicitis in children: a meta-analysis. JAMA pediatrics 171: 426-434.

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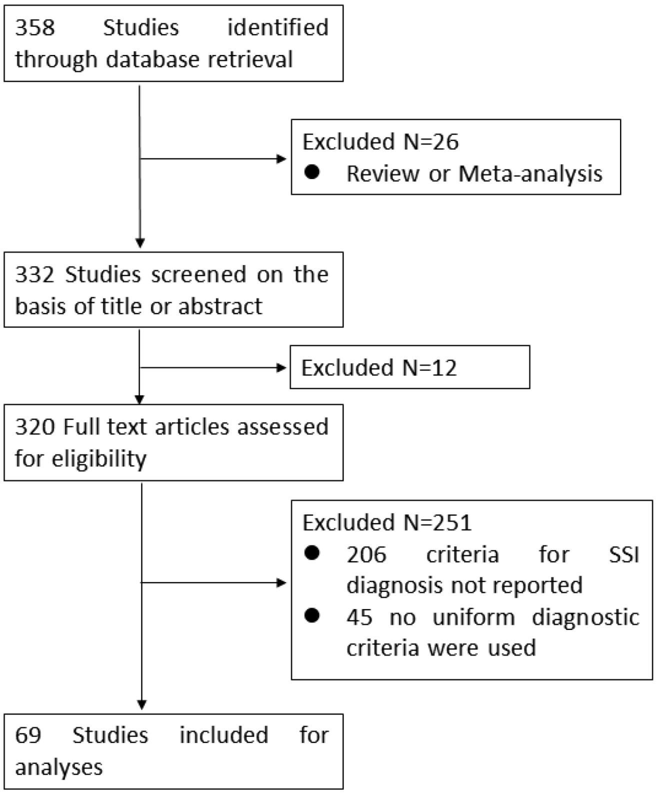
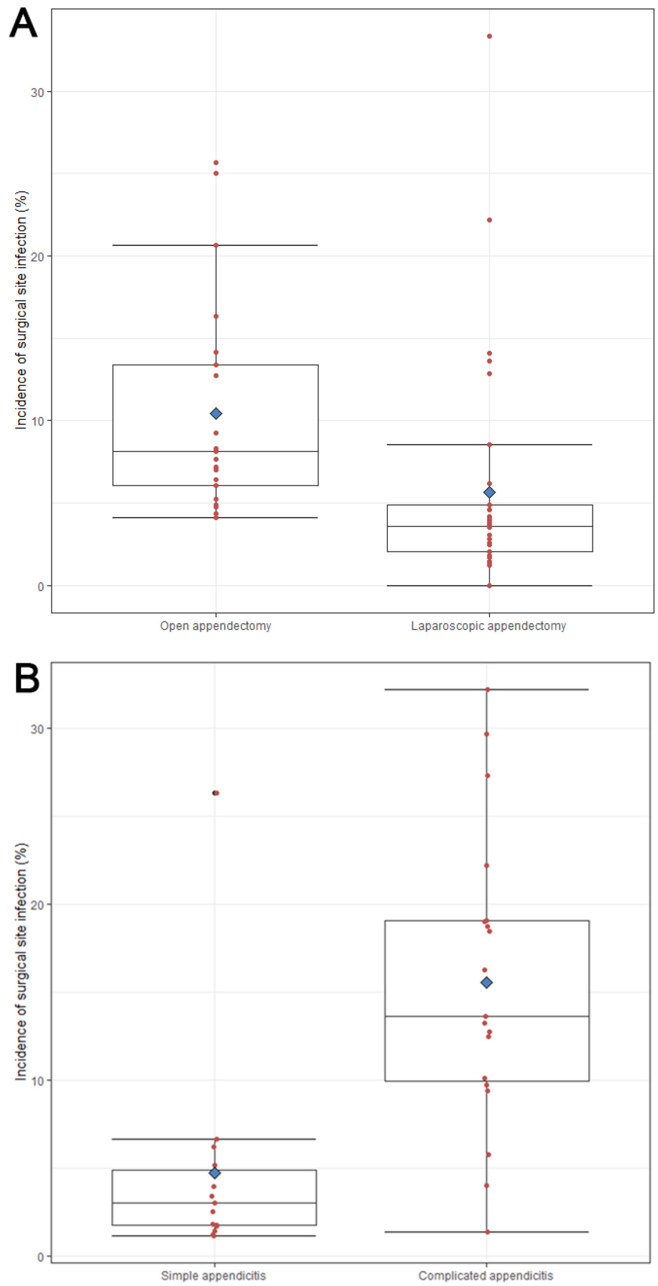
Conflict of interests: No conflict of interests is declared.

Annex – Supplementary Items

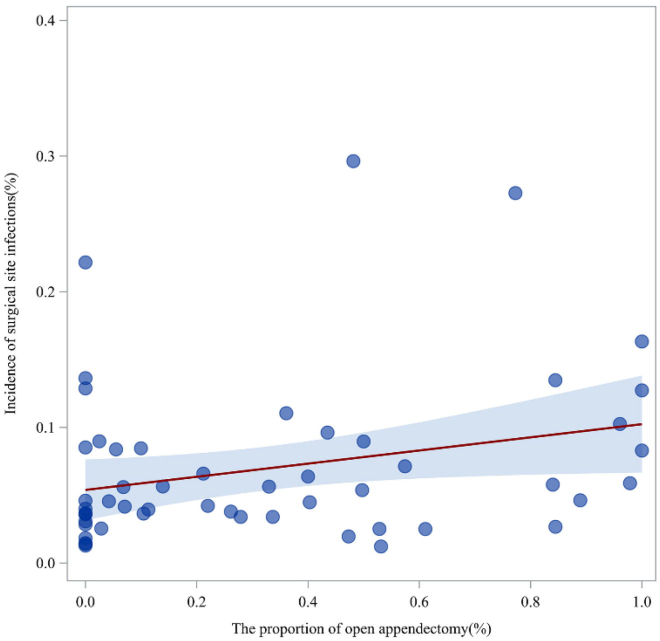
Supplementary Figure 1. Study flow.



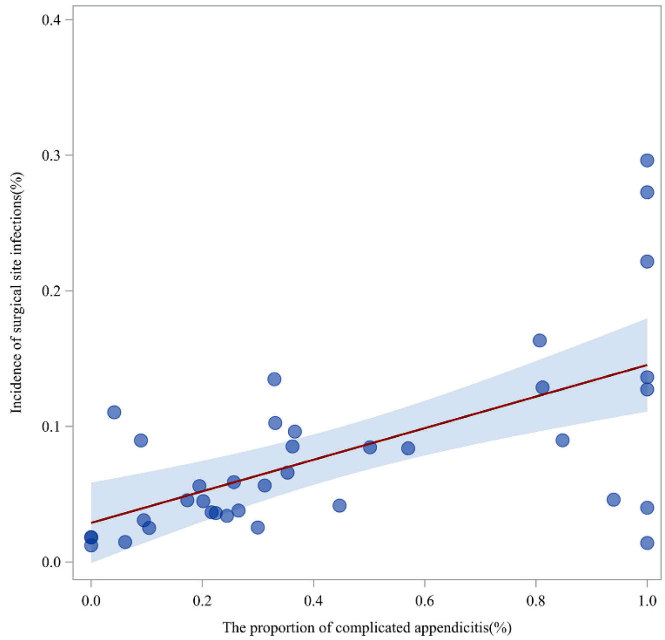
Supplementary Figure 2. Incidence of surgical site infections (**a**) according to surgical modality, 2000–2021; (**b**) according to type of appendicitis, 2000–2021.



Supplementary Figure 3. SSI rate after appendectomy by the proportion of open appendectomy.



Supplementary Figure 4. SSI rates after appendectomy by the proportion of complicated appendicitis.



Supplementary Table 1. Individual characteristics of the included studies.

No	First author	Year	Design	Country	Period	Population	Pattern of appendicitis	SSI in simple appendicitis (%)	SSI in complicated appendicitis (%)	Type of surgery	SSI in open Surgery (%)	SSI in laparoscopy (%)	Sampl e size	Total SSI
[1]	Álvarez-Moreno	2014	Cohort	Colombia	2008-2010	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	NR	NR	NR	947	37
[2]	Aranda-Narvaez	2014	Cohort	Spain	2007-2010	Adults	Catarrhal, Perforated, Suppurated, Gangrenous	4.59	32.17	Laparoscopy or Open Surgery	13.37	14.07	868	117
[3]	Aranda-Narváez	2010	Cohort	Spain	1997-2009	Children, Adolescents, Adults, Elderly	Suppurated, Gangrenous	NR	27.27	Laparoscopy or Open Surgery	NR	NR	22	6
[4]	Bae	2016	Cross sectional	Korea	2014-2016	Adults	Perforated, Suppurated, Gangrenous	NR	4.00	Laparoscopy	NR	4.00	25	1
[5]	Bae	2016	Cross sectional	USA	2010-2013	Children, Adolescents, Adults	Unclear	NR	1.40	Laparoscopy	NR	1.40	143	2
[6]	Bhangu	2013	Cohort	UK, Spain, Japan, Hong Kong, Australia, New Zealand	2012	Children, Adolescents, Adults, Elderly	simple, complex, normal	NR	NR	Laparoscopy or Open Surgery	6.43	2.07	3326	113
[7]	Bansal	2012	Cohort	Switzerlan d	NR	Children	Catarrhal, Perforated	1.44	18.75	Laparoscopy or Open Surgery	NR	NR	187	11
[8]	Boomer	2016	Cross sectional	USA	2010-2012	Children, Adolescents	Unclear	1.18	5.74	Laparoscopy or Open Surgery	5.26	2.47	1338	34
[9]	Brandt	2008	Cross sectional	Germany	2000-2004	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	NR	NR	NR	10969	264
[10]	Brummer	2009	Cohort	Germany	2004-2007	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	NR	14209	279
[11]	Cameron	2017	Cohort	USA	2012-2015	Children, Adolescents	Unclear	1.80	NR	Laparoscopy or Open Surgery	NR	NR	1389	25
[12]	Cho	2014	Cross sectional	Korea	2011-2012	Adults	Unclear	26.32	9.76	Laparoscopy	NR	12.87	101	13
[13]	Coakley	2011	Cohort	USA	2005-2010	Adults	Catarrhal, Perforated, Suppurated, Gangrenous	NR	NR	Laparoscopy or Open Surgery	NR	NR	728	61
[14]	Gandaglia	2014	Cohort	USA	2005-2011	Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	7.00	3.80	36880	1983

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[15]	Garcell	2016	Cohort	qatar	2013-2015	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Open Surgery	20.63	1.67	603	22
[16]	Giesen	2017	Cohort	Netherlands	2014-2015	Children, Adults	Catarrhal, Perforated, Suppurated, Gangrenous	3.40	12.44	Laparoscopy or Open Surgery	8.15	6.18	637	42
[17]	Harmon	2016	Cohort	USA	2007-2012	Children, Adolescents, Adults, Elderly	Non perforated	3.02	16.25	Laparoscopy or Open Surgery	25.00	4.18	411	23
[18]	Helling	2017	Cross sectional	USA	2009-2014	Adults	complicated, uncomplicated	NR	NR	Laparoscopy or Open Surgery	NR	NR	553	23
[19]	Horvath	2016	Cross sectional	Germany	2005-2013	Adults	Perforated, phelgmonous	NR	NR	Laparoscopy or Open Surgery	4.10	0.00	1516	38
[20]	Inigo	2006	Cohort	Spain	1998-2002	Adults	Unclear	NR	NR	NR	NR	NR	721	46
[21]	Jenkins	2016	Cohort	USA	2006-2011	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	NR	12410	422
[22]	Kapischke	2013	Case control	Germany	1999-2001	Children, Adolescents	Catarrhal, Perforated	NR	NR	Laparoscopy or Open Surgery	4.76	0.00	159	4
[23]	Kasatpibal	2006	Cohort	Thailand	2003-2004	Children, Adolescents, Adults, Elderly	Catarrhal	1.22	NR	Laparoscopy or Open Surgery	NR	NR	2139	26
[24]	Khan	2007	Cohort	United Kingdom	2006	Children, Adolescents, Adults, Elderly	Catarrhal, Perforated	NR	NR	Laparoscopy or Open Surgery	9.26	1.25	134	6
[25]	Kilic	2016	Cross sectional	Turkey	2004-2010	Children	Perforated	NR	12.72	Open Surgery	12.73	NR	110	14
[26]	Kim	2015	Cross sectional	Korea	2008-2013	Children, Adolescents, Adults, Elderly	Perforated, Suppurated, Gangrenous, Normal	NR	NR	Laparoscopy	NR	4.60	2587	119
[27]	Kim	2011	Cross sectional	USA	2005-2008	Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	7.64	4.87	3335	188
[28]	Kumar	2016	Cohort	Nepal	2015-2016	Adolescents, Adults	Catarrhal, Perforated, Suppurated, Gangrenous, Normal	NR	NR	Laparoscopy or Open Surgery	14.15	3.80	212	19
[29]	Le	2009	Cross sectional	USA	1997-2007	Children, Adolescents, Adults, Elderly	Catarrhal, Perforated, Gangrenous, Normal Appendix	NR	NR	Laparoscopy or Open Surgery	NR	NR	507	56
[30]	Michailidou	2015	Cross sectional	USA	2007-2013	Children, Adolescents	Perforated, nonperforated	NR	NR	Laparoscopy or Open Surgery	4.35	3.59	264	10
[31]	Jodra	2003	Cohort	Spain	1997-2000	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	NR	NR	NR	5780	459
[32]	Parcells	2009	Cohort	USA	1997-2007	Adults	Perforated, Not perforated	6.19	18.47	Laparoscopy or Open Surgery	NR	NR	1063	109
[33]	Park	2017	Cohort	Korea	2012-2014	Adults	Perforated, Gangrenous	NR	13.63	Laparoscopy	NR	13.63	1343	183
[34]	Pishori	2003	Cross sectional	Pakistan	1997-1999	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	NR	NR	NR	281	7
[35]	Romy	2008	Cross sectional	Switzerland	1998-2004	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	8.26	5.61	2468	176
[36]	Rotermann	2004	Cohort	Canada	1997-2000	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	NR	NR	NR	80867	3108
[37]	Saar	2016	Cross sectional	Estonia	2013-2014	Adults	Catarrhal, Perforated, Suppurated, Gangrenous, Normal	NR	NR	Laparoscopy or Open Surgery	NR	NR	266	15
[38]	Sanchez-Santana	2017	Cohort	Spain	2007-2015	Adults	Unclear	NR	NR	Laparoscopy or Open Surgery	4.90	2.60	930	43
[39]	Scarborough	2012	Cross sectional	USA	2005-2009	Children, Adolescents, Adults, Elderly	Ruptured, Non ruptured	NR	NR	Laparoscopy or Open Surgery	NR	NR	39122	1650
[40]	Shimizu	2014	Cross sectional	Japan	2000-2012	Adults	Catarrhal, Gangrenous	5.17	19.01	Open Surgery	16.33	NR	300	49
[41]	Soll	2016	Cohort	Switzerland	2009-2013	Children, Adolescents, Adults, Elderly	Perforated, non-perforated	NR	NR	Laparoscopy	NR	3.08	813	25
[42]	Staszewicz	2014	Cohort	Switzerland	1998-2011	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	NR	6383	407
[43]	Taguchi	2015	Clinical trial	Japan	2009-2014	Adults	complicated	NR	29.63	Laparoscopy or Open Surgery	25.64	33.33	81	24

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[44]	Troillet	2017	Cohort	Switzerland	2011-2015	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	7.20	3.50	15439	609
[45]	Wang-Chan	2017	Cross sectional	Switzerland	2013-2014	Children, Adolescents, Adults, Elderly	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	2.85	246	7
[46]	Watanabe	2011	Cross sectional	Japan	2005-2006	Adults	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	NR	101	17
[47]	Turner	2019	Case control	USA	2016	Adults	uncomplicated, complicated	1.74	10.12	Laparoscopy	NR	3.61	10357	374
[48]	Thong	2019	cohort	Australia	2016	Children, Adolescents, Adults, Elderly	uncomplicated, complicated	NR	NR	Laparoscopy or Open Surgery	NR	NR	1186	54
[49]	Somers	2019	Case control	USA	2013-2017	Children	Acute, complicated	2.50	19.07	Laparoscopy	NR	8.52	1549	132
[50]	Meijs	2019	cohort	Netherlands	2012-2017	Adults, Elderly	Unclear	NR	NR	Laparoscopy	NR	3.59	2616	94
[51]	Fields,	2019		USA	2016	Adults	uncomplicated, complicated	NR	NR	Laparoscopy	NR	3.67	11475	421
[52]	Duran poveda	2019	cohort	madrid	2008-2017	Children	Unclear	NR	NR	Laparoscopy or Open Surgery	NR	NR	412	11
[53]	Rodríguez	2019		Colombia	2014	Children	perforated, non-perforated	NR	NR	Laparoscopy or Open Surgery	NR	NR	1092	105
[54]	Choi	2019	Case control	South Korea	2015-2016	Children, Adolescents, Adults, Elderly	uncomplicated, complicated	NR	NR	Laparoscopy	NR	1.47	409	6
[55]	Litz	2017		USA	2015	Children	uncomplicated	1.83	NR	Laparoscopy	NR	1.83	5127	94
[56]	Hernandez	2017		USA	2008-2012	Children	Catarrhal, Perforated, Gangrenous, Normal	3.95	13.25	Laparoscopy or Open Surgery	NR	NR	331	28
[57]	Hernandez	2018		South Africa	2010-2016	Children	Catarrhal, Perforated, Gangrenous, Normal	6.67	9.41	Laparoscopy or Open Surgery	NR	NR	401	36
[58]	Del-Moral	2018	Clinical trial	spain	2009-2013	Adults	Unclear	NR	NR	Laparoscopy or Open Surgery	6.09	4.12	606	35
[59]	Rossidis	2020	Case control	usa	2013-2017	Children	Unclear	NR	NR	Laparoscopy	NR	1.28	1562	20
[60]	Ferguson	2020	Case control	usa	2013-2016	Children	perforated	NR	22.16	Laparoscopy	NR	22.16	379	84
[61]	Emile	2020	Case control	Egypt	2019-2020	Adolescents, Adults, Elderly	Unclear	NR	NR	Open Surgery	8.29	NR	205	17
[62]	Mohammed	2021	Cross sectional	Saudi Arabia	2013-2017	Children, Adolescents, Adults, Elderly	uncomplicated, complicated	3.60	8.39	Laparoscopy or Open Surgery	12.63	0.41	433	31
[63]	Sameh Hany	2021	Case control	Egypt	2018-2020	adult	uncomplicated, complicated	NR	51.43	Open Surgery	12.83	NR	343	44
[64]	Talal B	2021	cohort	USA	2016-2019	children	Perforated	NR	10.74	Laparoscopy	NR	10.74	149	16
[65]	Jothinathan	2021	Case control	Malaysia	NR	Adults	acute and Perforated	5.56	12.00	Open Surgery	8.20	NR	183	15
[66]	Sarah C	2020	Case control	USA	2014-2019	children	uncomplicated, complicated	0.86	16.50	Laparoscopy or Open Surgery	NR	NR	335	19
[67]	Bikas	2021	Cohort	Nepal	2017-2018	Adults	uncomplicated	13.33	NR	Open Surgery	13.33	NR	90	12
[68]	Swart	2021	Cohort	South Africa	2017	Children, Adolescents, Adults, Elderly	uncomplicated, complicated	11.90	53.25	Laparoscopy or Open Surgery	52.05	17.39	119	46
[69]	Mark A	2021	Case control	USA	2013-2015	children	uncomplicated	1.30	NR	Laparoscopy or Open Surgery	NR	NR	846	11