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REVIEW

Management and outcomes of acute appendicitis in children during the COVID-19 pandemic: a systematic review and meta-analysis

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Abstract

The COVID-19 pandemic has changed the way to manage the emergencies, as people faced fear of the hospitals, with possible delay in the diagnosis. Moreover, clinicians had to rearrange protocols for diagnosis and treatment. We aimed to assess whether COVID-19 pandemic influenced severity of inflammation, management, and outcomes of acute appendicitis (AA), when compared to the pre-COVID era. Using defined search strategy, two independent investigators identified those studies comparing pediatric AA during COVID-19 pandemic *versus* the pre-COVID-19 period. Meta-analysis was performed using RevMan 5.3. Data are mean ± SD. Of 528 abstracts, 36 comparative studies were included (32,704pts). Time from symptoms onset to surgery was longer during the pandemics compared to the pre-COVID-19 (1.6 ± 0.9 *versus* 1.4 ± 0.9 days; $p < 0.00001$). Minimally Invasive Surgery was similar during COVID-19 (70.4 ± 30.2%) *versus* control period (69.6 ± 25.3%; p = ns). Complicated appendicitis was increased during the pandemics (35.9 ± 14.8%) compared to control period (33.4 ± 17.2%; $p < 0.0001$). Post-operative complications were comparable between these two groups (7.7 ± 6.5% *versus* 9.1 ± 5.3%; p = ns). It seems that the COVID-19 pandemic influenced the time of diagnosis, severity of inflammation, and type of surgery. However, the number of post-operative complications was not different between the two groups, leading to the conclusion that the patients were correctly managed.

Level of Evidence Level 3 Meta-analysis on Level 3 studies

Keywords Acute appendicitis · COVID-19 · Children · Systematic review · Meta-analysis

Abbreviations

AA	Acute appendicitis
MIS	Minimally invasive surgery
NOM	Non-operative management

Introduction

Since the breakthrough of the Coronavirus-19 (COVID-19) pandemic, there have been a change and a rearrangement both in the society and in the worldwide healthcare [1–3].

During the lockdown, people were less prone to attend the emergency department (ED) due to the fear of contracting the COVID-19, leading to a delayed diagnosis of several diseases [1, 3–7].

Acute appendicitis (AA) is the most common pediatric surgical emergency, and its severity is strictly related to the time of diagnosis: a delayed diagnosis increases the risk of developing complications, such as abscess, peritonitis, sepsis, and wound infection [5, 8].

The gold standard of care for acute appendicitis is appendectomy (through a minimally invasive or open approach). Even if the non-operative management is a well-established procedure in adults, its use among children is not completely defined up to now [2, 8–10].

Although the COVID-19 affects adults more than children, the pandemic has also influenced the management of the pediatric surgical patient [2, 3, 11–13]. Coronavirus infection, in fact, can present with gastrointestinal symptoms in both adults and children, thus increasing the risk of misdiagnoses [2, 10, 14]. Moreover, during the lockdown, the surgical activity has been reduced to the sole emergency surgery and the conversion of peripheral hospitals into COVID

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hospitals has increased the risk of delayed diagnosis of acute appendicitis [2, 8, 11, 13].

The aim of our study was to assess whether the COVID-19 pandemic influenced the management of AA in children in:

- Diagnosis (age at diagnosis, time from symptoms onset and hospital presentation)
- Severity of inflammation
- Management (non-operative management, minimally invasive surgery and/or open surgery)
- Outcomes (length of hospital stay and post-operative complications).

Material and methods

Data sources and study selection

This study was registered on the international prospective register of systematic reviews PROSPERO (registration #CRD42022325941) (National institute for Health Research) [15]. The systematic review was drafted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [16].

A systematic review of the English literature was made using a defined search strategy (Table 1). Two investigators (MEM, GLa) independently searched scientific databases (PubMed, Cochrane Collaboration, Scopus, and Web of Science) looking for studies reporting on acute appendicitis during the COVID19 pandemic in children published up to September 2023. MeSH headings and terms used are "Acute appendicitis", "Appendicitis", "COVID-19", "SARS-CoV-2", ''Pediatric", and "Children" (Fig. 1). Reference lists were searched to identify relevant cross-references. Case reports, opinion articles, experimental studies, and case series with less than 10 patients were excluded. All grey literature publications (i.e. reports, theses, conference proceedings, bibliographies, commercial documentations, and official documents not published commercially) were excluded. Full text articles of potentially eligible studies were retrieved and independently assessed for suitability by two investigators (MEM, GLa). We included all studies (trials, cohort, and case–control) that reported at least one outcome of interest. Furthermore, we included in the meta-analysis only those studies comparing the management of acute appendicitis in children before and after the spreading of COVID19 pandemic. If two or more studies had overlapping patient cohorts, for each outcome measure we included only the article with the largest number of patients. Any disagreement over the eligibility of a specific study was resolved through the discussion with a third author (GLi).

Table 1 Defined search strategy

Publication	
Language	English
Time period	January 1950–September 2023
Subject	Human studies
Study type	Retrospective
	Prospective
	Case–control
	Cohort
Excluded	Case-report
	Case series (< 10 patients)
	Editorials
	Letters
	Grey literature
Keywords	COVID-19
	SARS-CoV-2
	Acute appendicitis
	Appendicitis
	Children
	Pediatric

Statistical analysis

Categorical variable frequencies were compared using Pearson's chi-square test or the two-tailed Fisher exact probability test, as appropriate. When median and range were reported, mean ± SD were estimated, as previously reported [17]. Meta-analysis of comparative studies was conducted with RevMan 5.4 [18]. Data are presented as risk ratio (RR) for categorical variables, and mean differences (MD) for continuous variables, along with 95% confidence intervals (CI) using the random-effects model, with p values shown for Z test for overall significance and I^2 statistic for heterogeneity. A p-value < 0.05 was considered statistically significant. Data are expressed as mean ± SD.

Quality assessment

Risk of bias for individual studies was assessed in duplicate (DDR and VC) using the methodological index for non-randomized studies (MINORS) [19]. Differences between the two reviewers (DDR and VC) were resolved through consensus and discussion with a third author (GLa). The total score for this 12-item instrument ranges 0–24 points with a validated "gold standard" cut-off of 19.8. We assessed the methodological quality for each outcome by grading the quality of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology [20]. Quality of evidence was rated as high, moderate, low, and very low for each

Fig. 1 Search strategy

PubMed/MEDLINE

1. (COVID-19 OR SARS-CoV-2).mp.
2. acute appendicit*adj2 OR appendicit*adj2).mp.
3. (child*adj2 OR pediatric*adj2).mp.
4. 1 AND 2 AND 3

Scopus

TITLE-ABS-KEY ((COVID-19) OR (SARS-CoV-2) AND (acute appendicitis) OR (appendicitis) AND (child OR pediatric))

Cochrane Collaboration

1. MeSH descriptor : COVID-19, SARS-CoV-2, acute appendicitis, appendicitis, child, pediatric
2. Explode all trees

Web of Science

TOPIC ((COVID-19) OR (SARS-CoV-2) AND (acute appendicitis) OR (appendicitis) AND (child OR pediatric))

outcome. Observational studies start with a low quality of evidence. The quality of evidence was rated down in the presence of risk of bias, inconsistency, indirectness, imprecision, and publication bias. For assessment of risk of bias in observational studies, we used the MINORS instrument. Inconsistency was determined according to heterogeneity. We produced I^2 values to assess heterogeneity. I^2 value of 0–40, 30–60, 50–90, and 75–100% were considered as low, moderate, substantial, and considerable heterogeneity, respectively. Imprecision was assessed using optimal information size (OIS), which was based on 25% relative risk reduction, 0.05 of α error and 0.20 of β error [21].

Results

Of 528 title/abstract screened, 129 full-text articles were analyzed, 43 studies entered the qualitative analysis [1–11, 13, 14, 22–51], and 36 papers were included in the meta-analysis [1–8, 11, 13, 22, 23, 25–28, 30–44, 46–50] (32,704 pts, Fig. 2).

The age at presentation of symptoms was similar during COVID-19 pandemic (10.6 ± 1.2 years) when compared to the pre-COVID-19 era (10.7 ± 1.2 years; p = ns, MD -0.22, 95% confidence intervals (CI) [-0.49, 0.05], I^2 = 95%; Fig. 3a). The mean time from symptoms onset to surgery was significantly lengthened in the COVID-19 period compared to the pre-pandemic era (1.6 ± 0.9 *versus*

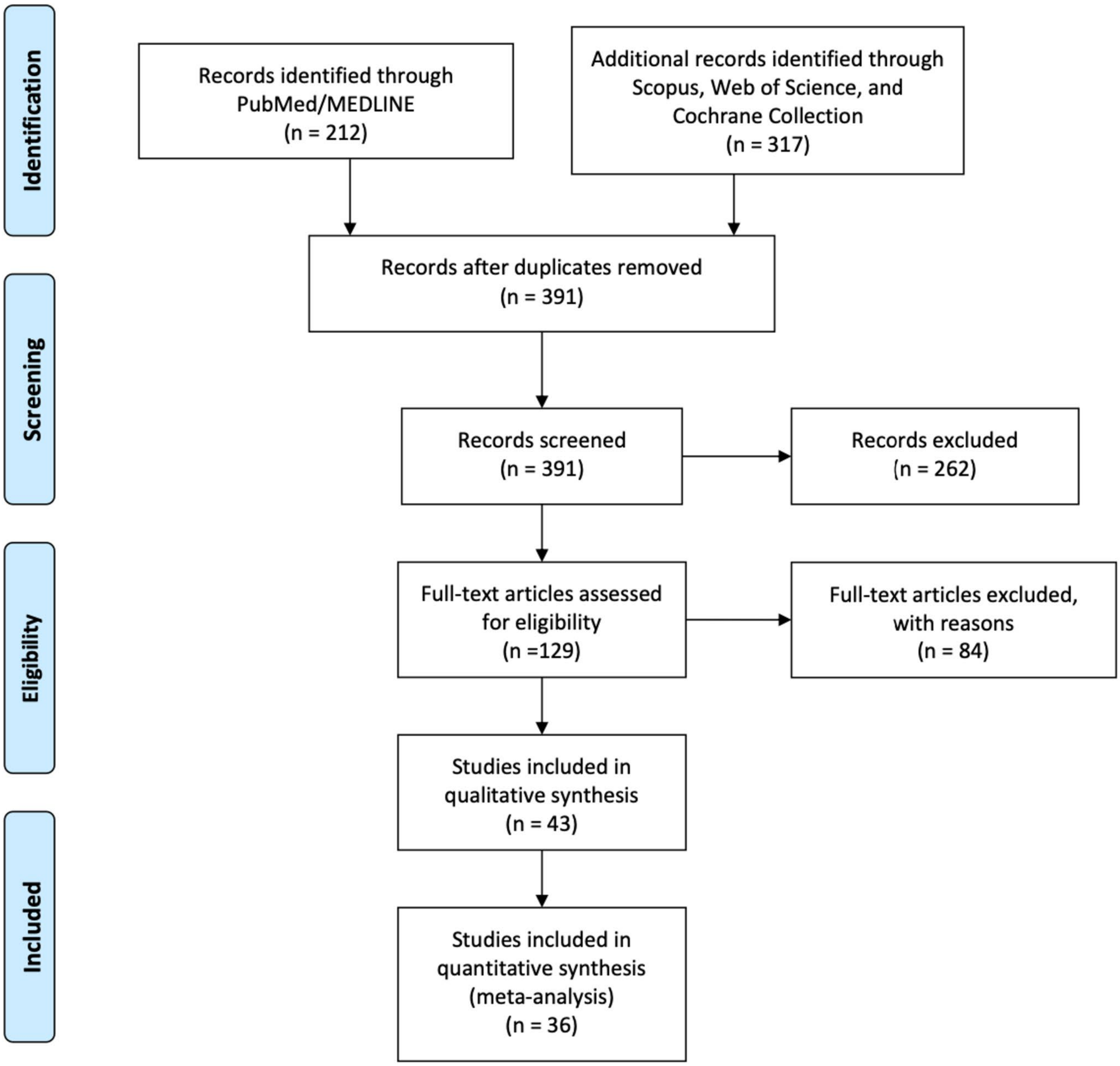


Fig. 2 Diagram of workflow in the systematic review and meta-analysis

1.4 ± 0.9 days, respectively; $p < 0.00001$, MD 0.24, 95% CI [0.16, 0.32], $I^2 = 95\%$; Fig. 3b).

When reported, minimally invasive surgery (MIS) did not appear to be decreased during the pandemic (4,468/6,343 cases, 70.4 ± 30.2%) *versus* the control period (4,303/6,178 cases, 69.6 ± 25.3%; p = ns, RR 0.99, 95% CI [0.94, 1.03], $I^2 = 80\%$, Fig. 4a). However, the number of complicated appendicitis was significantly increased during the pandemic (5,311/14,808 children, 35.9 ± 14.8%) compared to the control period (5,885/17,603 children, 33.4 ± 17.2%; $p < 0.0001$, RR 1.29, 95% CI [1.14, 1.45], $I^2 = 90\%$; Fig. 4b). Also, the non-operative management (NOM) was significantly increased during the COVID-19 pandemic compared to the previous period (1,199/11,138 patients, 10.8 ± 16.5% *versus* 555/11,937 patients, 4.6 ± 3.3%, respectively; $p = 0.02$; RR 1.77, 95% CI [1.10, 2.87], $I^2 = 83\%$; Fig. 4c). Moreover, the incidence of negative appendicitis was significantly decreased during the pandemic (382/8,872 children, 4.3 ± 8.5%) compared to the control period (564/8,216 children, 6.9 ± 9.8%); $p = 0.02$, RR 0.58, 95% CI [0.36, 0.92], $I^2 = 89\%$; Fig. 4d).

Nonetheless, we did not find a statistically significant increase of post-operative complications during the COVID-19 pandemic (876/11,387 patients, 7.7 ± 6.5%)

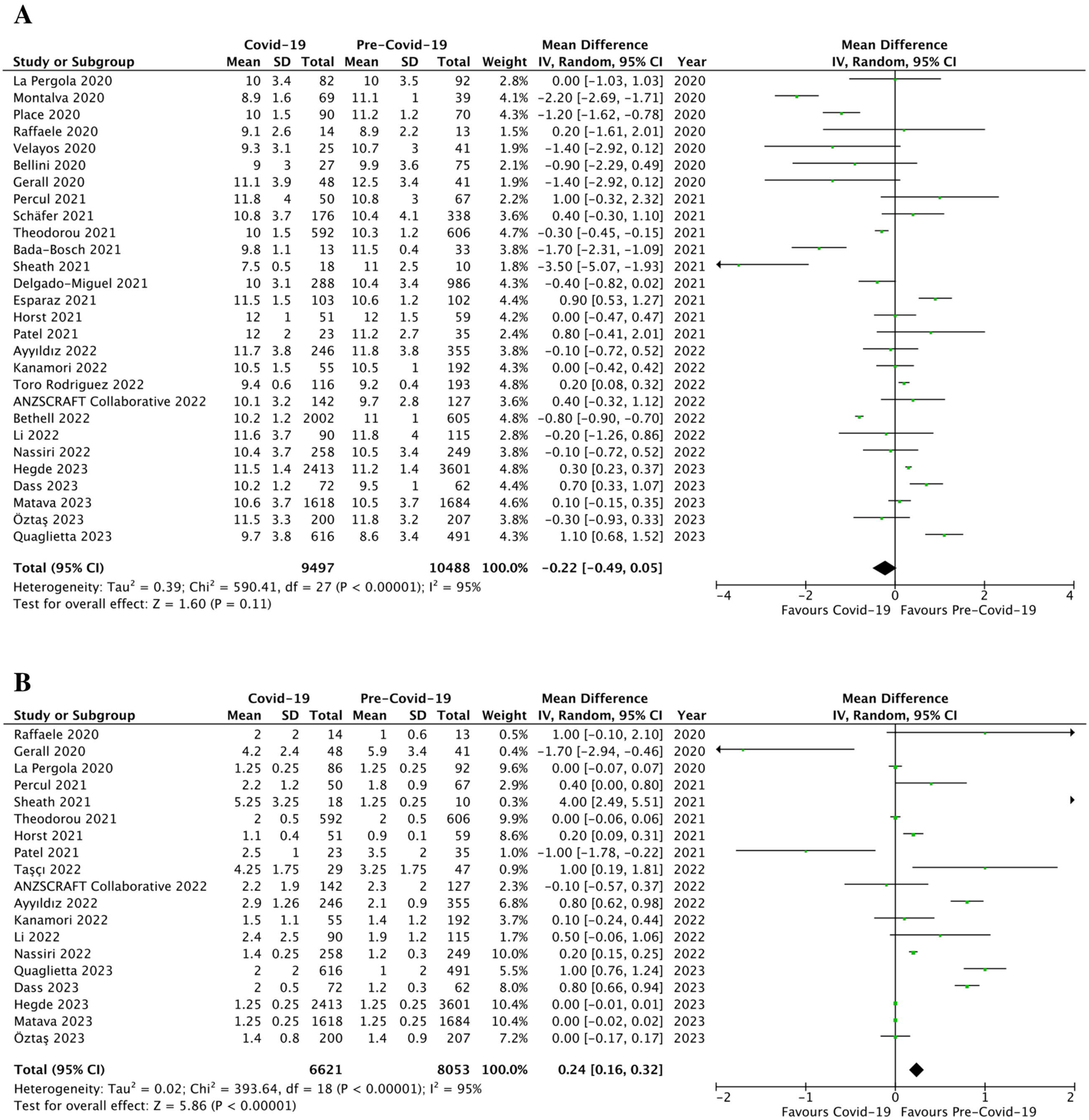


Fig. 3 Pre-operative data: forest plot comparison of patients during Covid-19 pandemic *versus* pre-Covid-19 era with regards age at presentation (**a**) and time from symptoms onset to surgery (**b**)

compared to the previous period (1,120/12,353 patients, 9.1 ± 5.3%; p = ns, RR 0.93, 95% CI [0.73, 1.18], I^2 = 73%, Fig. 5a). Finally, the length of hospital stay (LOS) was similar between the pandemic period (3.4 ± 2.1 days) and the pre-COVID-19 era (3.8 ± 1.4 days; p = ns, MD 0.02, 95% CI [-0.29, 0.34], I^2 = 95%; Fig. 5b).

Discussion

Acute appendicitis is the most common pediatric surgical emergency with up to 8% of children complaining of abdominal pain having a diagnosis of appendicitis [8].

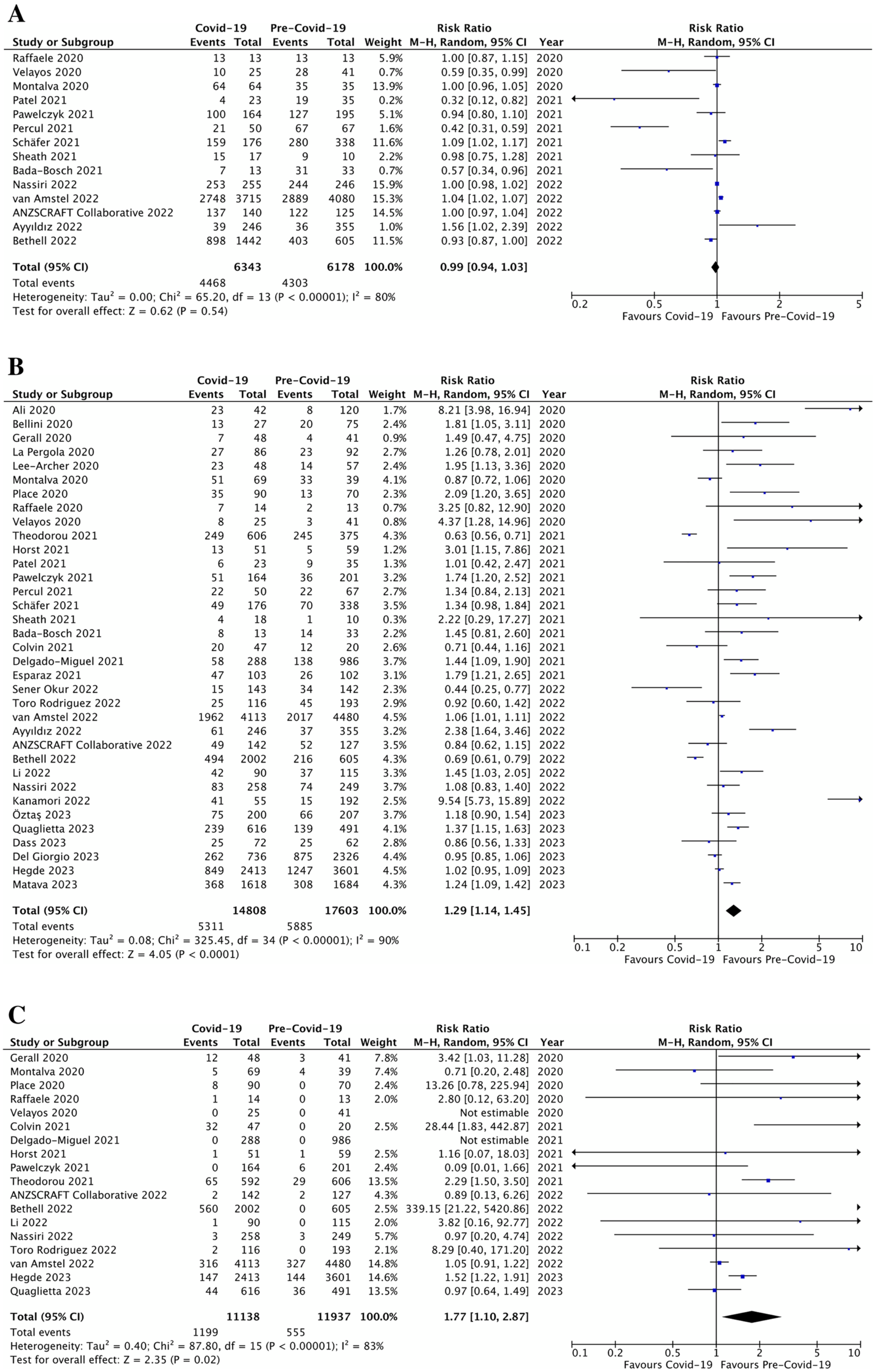


Fig. 4 Management of AA: forest plot comparison of patients during Covid-19 pandemic *versus* pre-Covid-19 era with regards minimally invasive appendectomies (**a**), the incidence of complicated appendicitis (**b**), non-operative management of acute appendicitis (**c**), and the rate of negative appendicitis (**d**)

D

Study or Subgroup	Covid-19 Events	Covid-19 Total	Pre-Covid-19 Events	Pre-Covid-19 Total	Weight	Risk Ratio M-H, Random, 95% CI	Year
Patel 2021	0	23	6	35	2.3%	0.12 [0.01, 1.95]	2021
Pawelczyk 2021	5	164	2	201	5.4%	3.06 [0.60, 15.59]	2021
Schäfer 2021	6	176	13	338	9.4%	0.89 [0.34, 2.29]	2021
Bethell 2022	58	2002	93	605	14.3%	0.19 [0.14, 0.26]	2022
Nassiri 2022	74	258	85	249	14.6%	0.84 [0.65, 1.09]	2022
van Amstel 2022	168	4113	220	4480	14.8%	0.83 [0.68, 1.01]	2022
Ayyıldız 2022	7	246	26	355	10.4%	0.39 [0.17, 0.88]	2022
Öztaş 2023	21	200	25	207	12.6%	0.87 [0.50, 1.50]	2023
Dass 2023	0	72	3	62	2.2%	0.12 [0.01, 2.34]	2023
Matava 2023	43	1618	91	1684	14.0%	0.49 [0.34, 0.70]	2023
Total (95% CI)		**8872**		**8216**	**100.0%**	**0.58 [0.36, 0.92]**	
Total events	382		564				

Heterogeneity: $Tau^2 = 0.38$; $Chi^2 = 79.89$, df = 9 (P < 0.00001); $I^2 = 89\%$
Test for overall effect: Z = 2.31 (P = 0.02)

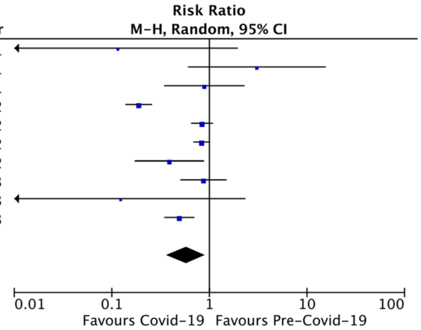
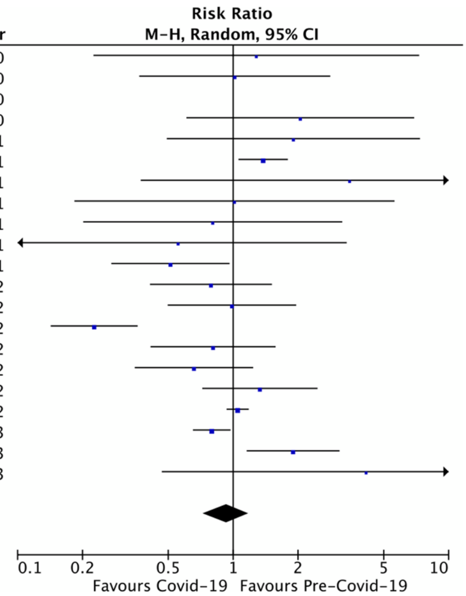


Fig. 4 (continued)

A

Study or Subgroup	Covid-19 Events	Covid-19 Total	Pre-Covid-19 Events	Pre-Covid-19 Total	Weight	Risk Ratio M-H, Random, 95% CI	Year
Gerall 2020	3	48	2	41	1.6%	1.28 [0.22, 7.30]	2020
Montalva 2020	9	69	5	39	3.7%	1.02 [0.37, 2.82]	2020
Raffaele 2020	0	14	0	13		Not estimable	2020
Velayos 2020	5	25	4	41	2.9%	2.05 [0.61, 6.92]	2020
Bada-Bosch 2021	3	13	4	33	2.5%	1.90 [0.49, 7.36]	2021
Delgado-Miguel 2021	62	288	154	986	9.5%	1.38 [1.06, 1.79]	2021
Horst 2021	3	51	1	59	1.1%	3.47 [0.37, 32.34]	2021
Patel 2021	2	23	3	35	1.7%	1.01 [0.18, 5.61]	2021
Percul 2021	3	50	5	67	2.4%	0.80 [0.20, 3.21]	2021
Sheath 2021	2	18	2	10	1.5%	0.56 [0.09, 3.36]	2021
Theodorou 2021	14	592	28	606	6.2%	0.51 [0.27, 0.96]	2021
ANZSCRAFT Collaborative 2022	15	142	17	127	6.0%	0.79 [0.41, 1.51]	2022
Ayyıldız 2022	13	246	19	355	5.8%	0.99 [0.50, 1.96]	2022
Bethell 2022	30	2002	40	605	7.7%	0.23 [0.14, 0.36]	2022
Li 2022	12	90	19	115	5.9%	0.81 [0.41, 1.57]	2022
Nassiri 2022	15	258	22	249	6.2%	0.66 [0.35, 1.24]	2022
Toro Rodriguez 2022	16	116	20	193	6.3%	1.33 [0.72, 2.46]	2022
van Amstel 2022	478	4113	496	4480	10.5%	1.05 [0.93, 1.18]	2022
Hegde 2023	137	2413	257	3601	10.0%	0.80 [0.65, 0.97]	2023
Quaglietta 2023	50	616	21	491	7.4%	1.90 [1.16, 3.12]	2023
Öztaş 2023	4	200	1	207	1.1%	4.14 [0.47, 36.72]	2023
Total (95% CI)		**11387**		**12353**	**100.0%**	**0.93 [0.73, 1.18]**	
Total events	876		1120				

Heterogeneity: $Tau^2 = 0.14$; $Chi^2 = 69.93$, df = 19 (P < 0.00001); $I^2 = 73\%$
Test for overall effect: Z = 0.61 (P = 0.54)



B

Study or Subgroup	Covid-19 Mean	Covid-19 SD	Covid-19 Total	Pre-Covid-19 Mean	Pre-Covid-19 SD	Pre-Covid-19 Total	Weight	Mean Difference IV, Random, 95% CI	Year
Velayos 2020	5.6	5.9	25	3.2	4.3	41	1.3%	2.40 [−0.26, 5.06]	2020
Theodorou 2021	2.25	0.75	592	2.5	1	606	24.1%	−0.25 [−0.35, −0.15]	2021
Sheath 2021	6.25	0.75	18	6	0.5	10	16.1%	0.25 [−0.21, 0.71]	2021
Toro Rodriguez 2022	2.4	0.9	116	2.1	0.8	193	22.5%	0.30 [0.10, 0.50]	2022
van Amstel 2022	3.5	1	4113	4	0.5	4480	24.7%	−0.50 [−0.53, −0.47]	2022
Sener Okur 2022	5.2	3.27	143	4.59	2.7	142	11.2%	0.61 [−0.09, 1.31]	2022
Total (95% CI)			**5007**			**5472**	**100.0%**	**0.02 [−0.29, 0.34]**	

Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 100.38$, df = 5 (P < 0.00001); $I^2 = 95\%$
Test for overall effect: Z = 0.15 (P = 0.88)

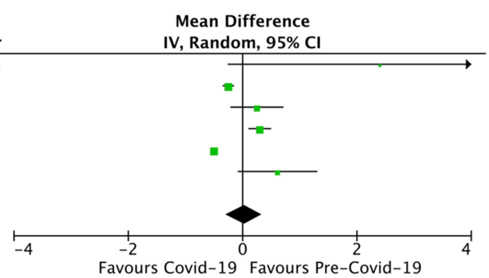


Fig. 5 Post-operative outcomes: forest plot comparison of patients during Covid-19 pandemic *versus* pre-Covid-19 era with regards post-operative complications (**a**) and the length of hospital stay (**b**)

The most common complication of AA is perforation, and its incidence is directly correlated with the duration of symptoms and age of the patient [5]. The higher rate of complicated appendicitis among very young children has to be referred to their difficulty to define their symptoms [5].

The increased rate of complicated appendicitis during the COVID-19 pandemic reported by several Authors was explained by the fear of contracting the virus in the hospitals, leading to a late referral to the emergency department and therefore to a delayed diagnosis [3, 5–8, 10, 12–14]. As a matter of fact, in our study we have found an overall increased time-lapse from symptoms onset to surgery that could be related to the finding of a significantly higher number of complicated appendicitis during the pandemic compared to the pre-pandemic era. Moreover, in our study the mean age at presentation was similar among the two study groups, thus removing any possible bias given by different age populations.

It has also been postulated that the COVID-19 infection itself could increase the rate of complicated appendicitis, due to the gastrointestinal manifestation of the disease and this assumption may also explain our results [6].

The management of children with AA during the pandemic is also controversial. Some Authors, in fact, postulated an increased risk of contagion during laparoscopy due to aerosolization of peritoneal fluids [2, 10, 22]. Therefore, the ESPES (European Society of Pediatric Endoscopic Surgeons) recommended the use of a closed system for CO_2 insufflation and de-sufflation, limiting the use of the electrocautery [51]. When analyzing our data, in fact, we did not find a reduced use of the minimally invasive surgery (MIS) during the pandemic when compared to the pre-COVID-19 period. However, we did find fewer negative appendicitis during the pandemic when compared to the pre-COVID-19 period.

Another question raised during the COVID-19 era is the use of the NOM as the first-line treatment of the AA. Some surgeons, in fact, preferred to avoid the use of NOM to reduce the overall length of hospital stay and to avoid the risk of failure of NOM that may have led to an increased risk of complications, length of hospital stays, and readmissions [2, 5, 8, 12]. Some others, however, preferred the use of NOM to limit hospital access and to reduce the number of surgical procedures, and this was especially true during the strict lockdown [9, 52]. Moreover, the ESPES suggested to consider the use of NOM, whenever safe for the patient [51]. Indeed, in our study, we found an overall increased use of the NOM in children during the pandemic when compared to the same period pre-COVID-19.

Nonetheless, despite the higher incidence of complicated AA, we did not find an increased number of postoperative complications as well as a lengthened hospital stay, as demonstrated by other Authors, thus leading to the conclusion that children were appropriately treated [53].

Limitation of the study

We are aware of the limitations of our study, which rely on the quality of the studies and data available in the literature, as any other meta-analysis.

All the 36 studies included in the meta-analysis were retrospective observational studies [1–8, 11, 13, 22, 23, 25–28, 30–44, 46–50]. None of the papers provided sample size calculations. As expected, a blinded evaluation of objective endpoints was not possible and groups were not contemporary, because of different time-period between cases and controls. Moreover, none of the study have reported with regards to the loss to follow-up and there were a broad lack of data regards the length of follow-up. Therefore, in our meta-analysis, none of the studies reached the gold standard cut-off on MINORS of 19.8 out of 24 (Supplementary file 1).

According to the GRADE methodology, the quality of evidence of the meta-analysis was low with regards all the pre-operative data (age at presentation, time from symptoms onset to surgery), the management of AA (minimally invasive appendectomies, incidence of complicated appendicitis, percentage of NOM, and percentage of negative appendicitis) and post-operative outcomes (incidence of complication) (Table 2). Although the data were obtained from a considerable number of studies, their considerable heterogeneity could generate possible bias.

However, when independently assessed by two authors (DDR and VC) using A Measurement Tool to Assess Systematic Reviews (AMSTAR) [54], the present systematic review and meta-analysis received a decent score (Supplementary file 2).

The PRISMA checklist was then completed (Supplementary file 3).

Conclusions

The correct management of children with acute appendicitis during the COVID-19 pandemic is still debated.

The number of complicated appendicitis has increased during this period, and it seems to be directly related to the delayed referral to the hospital.

Up to now the use of laparoscopy is not contraindicated in the COVID-positive patients. As a matter of fact, the use of the MIS during the pandemic was not decreased when compared to the pre-pandemic era.

Even if the delayed diagnosis could influence the outcomes, the incidence of complications seems not to be

Table 2 GRADE evidence profile [20] for the present meta-analysis

Quality assessment							No. of patients		Effect		Quality
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Cases	Controls	Relative (95% CI)	Absolute (95% CI)	
Age at presentation during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
28	OS	Moderate[a]	Considerable	Not serious	Serious[b]	None	9,474	10,488	–	MD 0.22 lower (from 0.49 lower to 0.05 higher)	⊗⊗OO Low
Time from symptoms onset to surgery during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
19	OS	Moderate[a]	Considerable	Not serious	Serious[b]	None	6,621	8,053	–	MD 0.24 higher (from 0.16 to 0.32 higher)	⊗⊗OO Low
MIS appendectomies during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
14	OS	Moderate[a]	Substantial	Not serious	Serious[b]	None	4,468/6,343 (70.4%)	4,303/6,178 (69.6%)	RR 0.99 (0.94, 1.03)	8 more per 1000 (from 48 more to 24 fewer)	⊗⊗OO LOW
Incidence of complicated appendicitis during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
35	OS	Moderate[a]	Considerable	Not serious	Serious[b]	None	5,311/14,808 (35.9%)	5,885/17,603 (33.4%)	RR 1.29 (1.14, 1.45)	25 more per 1000 (from 12 to 39 more)	⊗⊗OO Low
NOM during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
18	OS	Moderate[a]	Substantial	Not serious	Serious[b]	None	1,199/11,138 (10.8%)	555/11,937 (4.6%)	RR 1.77 (1.10, 2.87)	62 more per 1000 (from 8 to 151 more)	⊗⊗OO LOW
Negative appendicitis during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
10	OS	Moderate[a]	Considerable	Not serious	Serious[b]	None	382/8,216 (4.3%)	564/8,216 (6.9%)	RR 0.58 (0.36, 0.92)	26 fewer per 1000 (from 40 to 5 fewer)	⊗⊗OO Low
Complications during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
21	OS	Moderate[a]	Substantial	Not serious	Serious[b]	None	876/11,387 (7.7%)	1,120/12,353 (9.1%)	RR 0.93 (0.73, 1.18)	14 fewer per 1000 (from 54 fewer to 36 more)	⊗⊗OO LOW
LOS during Covid-19 vs. pre-Covid-19 era							Covid-19	Pre-Covid-19			
6	OS	Moderate[a]	Considerable	Not serious	Serious[b]	None	5,007	5,472	–	MD 0.02 higher (0.29 lower to 0.34 higher)	⊗⊗⊗O Very low

MIS minimally invasive surgery, *NOM* non-operative management, *LOS* length of hospital stay

[a]Bias due to possible confounding

[b]OIS not met

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate

Very low quality: We are very uncertain about the estimate increased during pandemic, thus leading to the conclusion that the choice of the surgical management (either open, MIS, or NOM) was still correct for each patient.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00383-023-05594-9.

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Data availability All data supporting the findings of this systematic review and meta-analysis are available within the paper and its Supplementary files. Further data with regards results (e.g. list of excluded studies with reasons) are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

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References

1. Ali S, Khan MA, Rehman IU et al (2020) Impact of covid 19 pandemic on presentation, treatment and outcome of paediatric surgical emergencies. J Ayub Med Coll Abbottabad 32:S621–S624 (**PMID: 33754519**)
2. Montalva L, Haffreingue A, Ali L et al (2020) The role of a pediatric tertiary care center in avoiding collateral damage for children with acute appendicitis during the COVID-19 outbreak. Pediatr Surg Int 36:1397–1405. https://doi.org/10.1007/s00383-020-04759-0
3. Bellini T, Rotulo GA, Carlucci M et al (2021) Complicated appendicitis due to diagnosis delay during lockdown period in Italy. Acta Paediatr 110(1959–60):1–2. https://doi.org/10.1111/apa.15756
4. MoratillaLapeña L, Delgado-Miguel C, Sarmiento Caldas MC et al (2021) Impact of SARS-CoV-2 pandemic on emergency department activity at the pediatric surgery unit of a third-level hospital. Cir Pediatr 1(34):85–89 (**PMID: 33826261**)
5. Gerall CD, DeFazio JR, Kahan AM et al (2021) Delayed presentation and sub-optimal outcomes of pediatric patients with acute appendicitis during the COVID-19 pandemic. J Pediatr Surg 56:905–910. https://doi.org/10.1016/j.jpedsurg.2020.10.008
6. Lee-Archer P, Blackall S, Campbell H et al (2020) Increased incidence of complicated appendicitis during the COVID-19 pandemic. J Paediatr Child Health 56:1313–1314. https://doi.org/10.1111/jpc.15058
7. Place R, Lee J, Howell J (2020) Rate of pediatric appendiceal perforation at a children's hospital during the COVID-19 pandemic compared with the previous year. JAMA Netw Open 1(3):e2027948. https://doi.org/10.1001/jamanetworkopen.2020.27948
8. Velayos M, Muñoz-Serrano AJ, Estefanía-Fernández K et al (2020) Influence of the coronavirus 2 (SARS-Cov-2) pandemic on acute appendicitis. An Pediatr (Engl Ed) 93:118–122. https://doi.org/10.1016/j.anpede.2020.04.010
9. Kvasnovsky CL, Shi Y, Rich BS et al (2021) Limiting hospital resources for acute appendicitis in children: Lessons learned from the U.S. epicenter of the COVID-19 pandemic. J Pediatr Surg 56:900–904. https://doi.org/10.1016/j.jpedsurg.2020.06.024
10. Mehl SC, Loera JM, Shah SR et al (2021) Favorable postoperative outcomes for children with COVID-19 infection undergoing surgical intervention: experience at a free-standing children's hospital. J Pediatr Surg 56:2078–2085. https://doi.org/10.1016/j.jpedsurg.2021.01.033
11. La Pergola E, Sgrò A, Rebosio F et al (2020) Appendicitis in children in a Large Italian COVID-19 pandemic area. Front Pediatr 9(8):600320. https://doi.org/10.3389/fped.2020.600320
12. Sheath C, Abdelrahman M, MacCormick A et al (2021) Paediatric appendicitis during the COVID-19 pandemic. J Paediatr Child Health 57(7):986–989. https://doi.org/10.1111/jpc.15359
13. Raffaele A, Cervone A, Ruffoli M et al (2020) Critical factors conditioning the management of appendicitis in children during COVID-19 pandemic: experience from the outbreak area of Lombardy, Italy. Br J Surg 107:e529. https://doi.org/10.1002/bjs.12004
14. Malhotra A, Sturgill M, Whitley-Williams P et al (2021) Pediatric COVID-19 and appendicitis: a gut reaction to SARS-CoV-2? Pediatr Infect Dis J 1(40):e49-55. https://doi.org/10.1097/INF.0000000000002998
15. PROSPERO international prospective register of systematic reviews. Available at: https://www.crd.york.ac.uk/prospero [on 25th Sep 2023]
16. Moher D, Liberati A, Tetzlaff J et al (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 21(6):e1000097. https://doi.org/10.1371/journal.pmed.1000097
17. Hozo SP, Djulbegovic B, Hozo I (2005) Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol 20(5):13. https://doi.org/10.1186/1471-2288-5-13
18. (2014) Review Manager (RevMan). The Nordic Cochrane Centre. The Cochrane Collaboration, Copenhagen
19. Slim K, Nini E, Forestier D et al (2003) Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. ANZ J Surg 73:712–716. https://doi.org/10.1046/j.1445-2197.2003.02748.x
20. Guyatt GH, Oxman AD, Vist GE et al (2008) GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 336:924–926. https://doi.org/10.1136/bmj.39489.470347.AD
21. Dupont WD, Plummer WD (1990) Power and sample size calculations: a review and computer program. Control Clin Trials 11:116–128. https://doi.org/10.1016/0197-2456(90)90005-m
22. Bada-Bosch I, de Agustín JC, de la Torre M et al (2021) Pediatric surgical activity during the SARS-CoV-2 pandemic: experience at a tertiary hospital. Cir Pediatr 1(34):28–33 (**PMID: 33507641**)
23. Patel M, Thomas JJ, Sarwary H (2021) We can reduce negative paediatric appendicectomy rate: a cohort study. Ann Med Surg (Lond) 5(71):102901. https://doi.org/10.1016/j.amsu.2021.102901

24 Basnet AT, Singh S, Thapa B et al (2021) Management of acute appendicitis during COVID-19 pandemic in a tertiary care centre: a descriptive cross-sectional study. JNMA J Nepal Med Assoc. https://doi.org/10.31729/jnma.6307
25. Horst KK, Kolbe AB, McDonald JS et al (2021) Imaging pediatric acute appendicitis during the coronavirus disease 2019 (COVID-19) pandemic: collateral damage is variable. Pediatr Radiol 51:1991–1999. https://doi.org/10.1007/s00247-021-05128-2
26. Esparaz JR, Chen MK, Beierle EA et al (2021) Perforated appendicitis during a pandemic: the downstream effect of COVID-19 in children. J Surg Res 268:263–266. https://doi.org/10.1016/j.jss.2021.07.008
27. Percul C, Cruz M, Meza AC et al (2021) Impact of the COVID-19 pandemic on the pediatric population with acute appendicitis: experience at a general, tertiary care hospital. Arch Argent Pediatr 119:224–229. https://doi.org/10.5546/aap.2021.eng.224
28. Colvin D, Lawther S (2021) A surge in appendicitis: management of paediatric appendicitis during the COVID-19 surge in the royal belfast Hospital for sick children. Ulster Med J 90:86–89 (**PMID: 34276086**)
29. Yock-Corrales A, Lenzi J, Ulloa-Gutiérrez R et al (2021) Acute abdomen and appendicitis in 1010 pediatric patients with COVID-19 or MIS-C: a multinational experience from Latin America. Pediatr Infect Dis J 40(10):e364–e369. https://doi.org/10.1097/INF.0000000000003240
30. Theodorou CM, Beres AL, Nguyen M et al (2021) Statewide impact of the COVID pandemic on pediatric appendicitis in California: a multicenter study. J Surg Res 267:132–142. https://doi.org/10.1016/j.jss.2021.05.023
31. Schäfer FM, Meyer J, Kellnar S et al (2021) Increased incidence of perforated appendicitis in children during COVID-19 pandemic in a Bavarian multi-center study. Front Pediatr 9:683607. https://doi.org/10.3389/fped.2021.683607
32. Kanamori D, Kurobe M, Sugihara T et al (2022) Increase in pediatric complicated appendicitis during the COVID-19 pandemic: a multi-center retrospective study. Surg Today 52:1741–1745. https://doi.org/10.1007/s00595-022-02529-0
33 Bethell GS, Gosling T, Rees CM et al (2022) Impact of the COVID-19 pandemic on management and outcomes of children with appendicitis: the children with appendicitis during the coronavirus pandemic (CASCADE) study. J Pediatr Surg 57(10):380–385. https://doi.org/10.1016/j.jpedsurg.2022.03.029
34 Nassiri AM, Pruden RD, Holan CA et al (2022) Pediatric appendicitis in the time of the COVID-19 pandemic: a retrospective chart review. J Am Coll Emerg Physicians Open. https://doi.org/10.1002/emp2.12722
35. Collaborative ANZSCRAFT, Roberts K (2022) Impact of COVID-19 on appendicitis presentations in children in Australia and New Zealand. ANZ J Surg 92:736–741. https://doi.org/10.1111/ans.17566
36. Li C, Saleh A (2022) Effect of COVID-19 on pediatric appendicitis presentations and complications. J Pediatr Surg 57:861–865. https://doi.org/10.1016/j.jpedsurg.2021.12.047
37. Delgado-Miguel C, Garcia Urbán J, Del Monte FC et al (2022) Impact of the COVID-19 pandemic on acute appendicitis in children. J Health Qual Res 37:225–230. https://doi.org/10.1016/j.jhqr.2021.12.005
38. Pawelczyk A, Kowalska M, Tylicka M et al (2021) Impact of the SARS-CoV-2 pandemic on the course and treatment of appendicitis in the pediatric population. Sci Rep 14(11):23999. https://doi.org/10.1038/s41598-021-03409-2
39. van Amstel P, El Ghazzaoui A, Hall NJ et al (2022) Paediatric appendicitis: international study of management in the COVID-19 pandemic. Br J Surg 14(109):1044–1048. https://doi.org/10.1093/bjs/znac239
40. Hegde B, Garcia E, Hu A et al (2023) Management of pediatric appendicitis during the COVID-19 pandemic: a nationwide multicenter cohort study. J Pediatr Surg 58:1375–1382. https://doi.org/10.1016/j.jpedsurg.2022.08.005
41. Taşçı A, Gürünlüoğlu K, Yıldız T et al (2022) Impact of COVID-19 pandemic on pediatric appendicitis hospital admission time and length of hospital stay. Ulus Travma Acil Cerrahi Derg. https://doi.org/10.14744/tjtes.2021.06777. (**English**)
42. Toro Rodríguez MG, Dore Reyes M, MartínezCastaño I et al (2022) Have acute appendicitis complications increased in children as a result of SARS-CoV-2? Cir Pediatr. https://doi.org/10.54847/cp.2022.03.16. (**English, Spanish PMID: 35796085**)
43. SenerOkur D, Memetoglu ME, Edirne Y (2022) Impact of the COVID-19 pandemic and the restrictions on pediatric appendicitis in Turkey: a single-center experience. Pediatr Int 64:e15272. https://doi.org/10.1111/ped.15272
44. Ayyıldız HN, Mirapoglu S, Yıldız ZA et al (2022) What has changed in children's appendicitis during the COVID-19 pandemic? Ulus Travma Acil Cerrahi Derg 28:1674–1681. https://doi.org/10.14744/tjtes.2021.51000
45. Iantorno SE, Skarda DE, Bucher BT (2023) Concurrent SARS-COV-19 and acute appendicitis: management and outcomes across United States children's hospitals. Surgery 173:936–943. https://doi.org/10.1016/j.surg.2022.12.004
46. Del Giorgio F, Habti M, Merckx J et al (2023) Investigating changes in incidence and severity of pediatric appendicitis during the COVID-19 pandemic in Canada- an interrupted time series analysis. World J Pediatr 19:288–292. https://doi.org/10.1007/s12519-022-00656-9
47. Quaglietta PR, Ramjist JK, Antwi J et al (2023) Unanticipated consequences of COVID-19 pandemic policies on pediatric acute appendicitis surgery. J Pediatr Surg 58:931–938. https://doi.org/10.1016/j.jpedsurg.2023.01.021
48. Öztaş T, Bilici S, Dursun A (2023) Has the frequency of complicated appendicitis changed in children in the first year of the COVID-19 pandemic? Ann Pediatr Surg 19:3. https://doi.org/10.1186/s43159-022-00235-7
49. Dass D, Hotonu S, McHoney M et al (2023) Prospective study of laparoscopic management of appendicitis during the COVID pandemic in a single paediatric centre. Afr J Paediatr Surg 20:40–45. https://doi.org/10.4103/ajps.ajps_181_21
50. Matava CT, Tighe NTG, Baertschiger R et al (2023) Patient and process outcomes among pediatric patients undergoing appendectomy during the COVID-19 pandemic: an international retrospective cohort study. Anesthesiology 139:35–48. https://doi.org/10.1097/ALN.0000000000004570
51. Pini Prato A, Conforti A, Almstrom M et al (2020) Management of COVID-19-positive pediatric patients undergoing minimally invasive surgical procedures: systematic review and recommendations of the board of European society of pediatric endoscopic surgeons. Front Pediatr 8:259. https://doi.org/10.3389/fped.2020.00259
52. Emile SH (2022) Finding a place for non-operative management of acute appendicitis: COVID-19 as an example. Am J Surg 223:605–606. https://doi.org/10.1016/j.amjsurg.2021.09.003
53. Head WT, Parrado RH, Cina RA (2023) Impact of the coronavirus (COVID-19) pandemic on the care of pediatric acute appendicitis. Am Surg 89:1527–1532. https://doi.org/10.1177/00031348211067995
54. Shea BJ, Grimshaw JM, Wells GA et al (2007) Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol 7:10. https://doi.org/10.1186/1471-2288-7-10

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