Quality Metrics for Emergency Abdominal Surgery in Children: A Systematic Review

Short Running Title: Quality Metrics in Emergency Paediatric Surgery

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Abstract

Background

There is variation in care quality and outcomes for children undergoing emergency abdominal surgery, such as appendicectomies. Addressing this requires paediatric-specific quality metrics. The aim of this study was to identify perioperative structure and process measures which are associated with improved outcomes for these children.

Methods

We performed a systematic review searching MEDLINE, Embase, CINAHL, the Cochrane Library, and Google Scholar for articles published between 01/01/80 and 29/09/20 about the perioperative care of children undergoing emergency abdominal surgery. We also conducted secondary searching of references and citations and included international professional publications.

Results

Three-hundred and eighty-three peer-reviewed articles and eighteen grey literature publications were identified and analysed. High grade evidence pertaining to the perioperative care of this patient group is limited. Most of the evidence available relates to improving diagnostic accuracy through the use of pre-operative blood testing, imaging and clinical decision tools. Processes associated with clinical outcomes include time lapse between time of presentation or initial assessment and surgery, and the use of particular analgesia and antibiotic protocols. Structural factors identified include hospital and surgeon caseload and the use of perioperative care pathways.

Conclusions

This review summarises the structural and process measures associated with outcome in paediatric emergency abdominal surgery. Such measures provide a means of evaluating care and identifying areas of practice which require quality improvement, especially in children with appendicitis.

Study Registration: Prospero CRD42017055285.

Key Words:

Acute Abdomen, Appendicitis, Child, Health Services Research, Perioperative Care, Quality of Healthcare, Surgical Procedure

Introduction

Children's emergency surgery is a clinical area for which significant variation in care has been repeatedly identified. Variation has been demonstrated in relation to both the manner in which patients are treated and in the subsequent outcomes reported. [1–6] Where unwarranted variation exists, there may be room for improvement. The National Emergency Laparotomy Audit (NELA) established in England and Wales to identify variations in adult care has been highly effective at improving outcome.[7] NELA has been used to drive quality improvement initiatives at local level and as a platform to undertake randomised trials where equipoise exists for specific interventions or pathways.[7 8]

Initiatives aiming to improve quality of care must first determine how to define quality and what specifically to measure. Clinical outcomes have traditionally been used to measure performance, but these may not provide sufficient evidence of care quality as they are influenced by other factors including case-mix, and wider societal influences such as deprivation.[9] Structural measures relate to the organisation of care, while processes refer to the investigations, treatments and other interventions received by the patient.[10] When specific processes or structures are known to improve outcome, their measurement gives not only a description of the state of play but also provides insight into what can be done to improve care.[9] The relationship between such measures and outcome in adult patients undergoing emergency abdominal surgery has been well reported.[7 11] The aim of this systematic review was to identify structures and processes associated with outcome in children. Our specific research questions are:

1. *What peri-operative structure and process measures are there which are associated with outcome in children undergoing emergency abdominal surgery?*
2. *What is the level of evidence underpinning these measures?*

Methods

This study is registered with PROSPERO (CRD42017055285) where the protocol is available to view. Methods and reporting conform to the Preferred Reporting Items for Systematic Reviews and Meta-analyses.[12] MEDLINE, Embase, CINAHL, the Cochrane Database of Systematic Reviews and the Cochrane Central Register of Controlled Trials were searched for articles published between 01/01/80 and 29/09/20 relating to the perioperative care of children (aged 1 – 18 years old) undergoing emergency abdominal surgery. Secondary searching included manual searching of references not identified in the primary search and of citations listed in Web of Science. We also searched the grey literature database Google Scholar, and included international professional publications and guidelines. We limited the search to English language human studies. The full search strategy is detailed in Appendix 1.

Definitions for the purposes of this review:

Perioperative Care: every aspect of patient care before, during and after surgery except those relating to the technical conduct of surgery e.g. surgical approach.[13]

Emergency: Urgent, immediate, or expedited presentations and or interventions as described by the National Confidential Enquiry into Patient Outcome and Death. [14]

Child / Children: 1 to 18 years old.

Abdominal Surgery: laparotomy, laparoscopy, or other incisional approaches, undertaken by a surgeon in an operating theatre requiring the support of an anaesthetist but excluding

organ transplants, insertion or removal of dialysis catheters, surgery relating to trauma, and Caesarean sections.

Study Selection Criteria

We screened titles and abstracts for relevance. Ten percent of the included studies were screened independently by both reviewers. Studies were included if the median or mean population age was > 12 months and studies involving adults were included if paediatric data was analysed and presented as an independent cohort. Studies with fewer than 50 participants, case series and conference abstracts were excluded, as were those comparing specific surgical or radiological techniques. Studies comparing different specific antibiotic regimens were also excluded as there may be geographical variation in recommendations due to differences in local flora. Papers published in the grey literature were included if they reported expert opinion in the form of guidelines or protocols.

Outcomes of interest were misdiagnosis, complications, hospital stay, and mortality. Increased diagnostic accuracy was considered a surrogate for reduced misdiagnosis.

Data Extraction and Quality Assessment of Included Studies:

Study characteristics capturing methodological quality and outcome were extracted independently by two reviewers with complete agreement on the sample reviewed by both. Characteristics included study type, number of participants, number of study sites, prospective or retrospective nature, inclusion and exclusion criteria, intervention and outcome of interest, key findings and potential sources of bias. Studies were considered to support a particular measure if demonstrating a significant improvement in outcome ($p <$

0.05). Studies focused on improving diagnostic accuracy, specifically, were included if the study utilised an objective test of diagnostic accuracy such as the sensitivity and specificity, the positive and negative predictive value, the likelihood ratios for the respective test results, or those using the Receiver Operating Characteristic curve. Study quality was ranked using a modified Oxford Centre for Evidence-based Medicine scale.[15] Consideration was given to meta-analysis for interventional studies, and where not appropriate, a narrative synthesis provided. Trials were assessed for bias using the Cochrane Risk of Bias Tool.[16] Study findings were grouped according to the structure or process measure being examined and are presented as a tabular summary.

Results

The initial search yielded 51044 articles with 167 meeting the inclusion criteria. Two hundred and sixteen further articles were identified during the secondary searches, and eighteen from the grey literature (Figure 1).

Three hundred and sixty-nine peer-reviewed papers specifically investigated children with appendicitis; 331 focused on processes, 38 on structures. Thirteen papers investigated children with other acute abdominal pathologies and one paper included both cohorts.

Quality of the Evidence

The characteristics of the included studies are found in Appendix 2 (eTable 1). Most are large retrospective cohort studies. Overall, 43% were prospective in nature, 4.4% provided level 1 evidence, and 85% were cohort studies. Participant numbers varied significantly. Studies reviewing structural factors were larger with a mean of 36,717 participants

compared with 3841 for process measures. Risk of bias in the 17 randomised controlled trials (RCTs) varied with only four identified as having a low risk (Appendix 2, eTable 2).

PEER-REVIEWED LITERATURE

Processes Measures: Appendectomy Cohort

The peer-reviewed literature identified 10 relevant processes which influence outcome (Table 1), most of which were related to improving diagnostic accuracy. Additional processes identified included the time to surgery and use of analgesia and antibiotics.

Diagnostic Accuracy

Blood testing was most frequently investigated with 96% of these studies reporting a correlation between white blood cell count (109 studies), neutrophil count (36 studies), or C Reactive Protein (78 studies) and a diagnosis of appendicitis. Four additional papers reported a diagnostic benefit when measuring specific urinary markers.

The merits of using radiological imaging was evaluated in 119 papers. Modalities included ultrasound (US), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), or a combination of these in an imaging protocol. Seventy-nine out of 85 papers reported that US improved diagnostic accuracy. Ten additional studies investigated point-of-care US (POCUS), nine of which reported favourably. Twenty-eight papers advocated for CT usage while six refuted this. Sixteen studies, all published since 2012, support the use of MRI: in eight, MRI was the primary imaging modality, and in the remainder, it was used when US findings were equivocal.

Eighty-one studies investigated the influence of clinical decision tools (CDTs) on diagnosis. The forty-four different CDTs reviewed were heterogenous with varying combinations of clinical signs, symptoms, laboratory tests and imaging. The Pediatric Appendicitis Score (PAS) was reported as being useful in 26 studies involving 15081 participants.[17] This compares to 3 studies which found a poor correlation between the score and diagnosis (365 participants). The Alvarado score (AS) was also found to be useful in 18 studies (8208 participants) compared with 6 studies (823 participants) where it was not.[18] Four studies reported experienced clinician assessment to be more accurate than using the PAS and AS alone due to difficulty identifying a reliable cut off score. Several additional externally validated scores have also been investigated including the Appendicitis Inflammatory Score, Christian tool, Pediatric Appendicitis Risk calculator, Kharbanda, Heidelberg and Sheera scores.

Time to Surgery

Twenty studies investigated the impact of the time taken from symptom development, initial review or admission to surgery. Most reported better outcomes in children with inpatient waits of less than 24 hours with four reporting waits of less than 12 hours improved outcome.

Analgesia

Twenty papers investigating analgesic use were identified. There was insufficient homogeneity in the intervention and outcome to undertake a meta-analysis for the randomised trials included, therefore a narrative synthesis is presented here.

In the emergency room intravenous morphine (0.05 – 0.1 mg/kg) reduced pain to a greater[19] or similar degree[20] to placebo without altering clinical diagnostics.

In the post-operative phase the literature supports a multimodal analgesia approach. Five papers reported that non-steroidal anti-inflammatory drugs reduced pain scores and/or opioid requirements. Intravenous paracetamol 10 mg/kg was of limited use but this dose is significantly less than routinely used.[21] Local anaesthetic wound infiltration improves early postoperative pain,[22] although this may have little additional benefit over the use of paracetamol, diclofenac and morphine.[23] Atomised local anaesthetic spray was not useful, but bilateral rectus sheath blocks resulted in a three-fold reduction in opioid requirements [24 25] Gabapentin also has opioid-sparing qualities,[26] while intravenous lidocaine reduced non-opioid analgesic usage but did not change the use of opioids themselves.[27]

The evidence relating to post-operative opioids is less clear cut. Four papers were identified. One reported a correlation between continuous infusions or patient-controlled analgesia (PCA) and prolonged hospital stay, although disease severity is a potential confounder.[28] Two studies suggested discharge prescriptions in simple appendicitis are associated with complications such as constipation.[29 30] Significant variation was also noted in type, dosing and duration of prescriptions. Another study reported worse parental satisfaction in children receiving opioids (codeine or oxycodone) with no analgesic benefit over paracetamol and ibuprofen, however the additional analgesics administered in the two groups were not comparable and the method used to measure satisfaction was not reported.[31]

A study investigating postoperative intravenous ketamine reported nil significant reduction in PCA opioid consumption although this may have been underpowered, and significant side effects were noted, likely due to the high dose used. [32]

Antibiotics

Seventeen antibiotics papers were identified. Meta-analysis was not possible because of the heterogeneity of the regimens evaluated. Three studies reported antibiotics are unnecessary in simple appendicitis. In contrast, a 5-7 day course of antibiotics reduced infections in complicated disease (perforated or gangrenous appendicitis),[33] with ten additional papers sanctioning the use of either a shortened course or early transition from intravenous to enteral antibiotics.

Processes Measures: Non-Appendectomy Cohort

Twelve studies retrieved from the literature pertaining to children with an acute abdomen due to pathologies other than appendicitis identified three processes. These were the use of diagnostic imaging, pre-operative analgesia, which has been shown not to impede diagnosis, and time to surgery.[34 35] Worse outcomes were noted in children with bowel obstruction if surgery was delayed by more than 12 hours.[36]

Structural Measures: Appendectomy Cohort

Thirty-seven articles investigated structures involved children with appendicitis (Table 1). Structures identified include hospital type and location, institutional and surgeon caseload, specialty of responsible team and the use of perioperative pathways of care.

The literature reveals a complex relationship between hospital type and outcome. Seventy-eight percent of studies found complications and re-interventions were lower in specialist paediatric centres (SPCs), but half reported prolonged inpatient stays in these specialist sites. Children in SPCs, however, are younger and more complex,[5 6 37–40] and the benefits seen when treated in such a centre were lost once age and hospital volume were adjusted for.[5 6 37 41 42] A similar relationship was seen when comparing urban with rural hospitals.[43–45] In complicated appendicitis hospital stays are shorter in non-teaching hospitals than teaching hospitals.[45 46]

Five studies reviewed institutional caseload, with three reporting an inverse relationship between caseload and deleterious outcome[42 47–50] A fifty percent reduction in the negative appendectomy rate was noted for every additional 1000 appendectomies perfomed.[49] Higher surgeon caseload is similarly beneficial with a reduction in the odds of morbidity of 15% for each 20 cases per year.[42]

Evidence regarding which specialty is best placed to provide care was equivocal. Three studies reported reduced complications or negative appendectomy rates (NAR) in children managed by specialist paediatric surgeons (PS) compared with general surgeons (GS).[51–54] Eight reported no difference between the groups,[37 53 55–60] and five studies found that children cared for by PSs stayed in hospital longer with a maximum difference of 24 hours. Although, children in the specialist cohorts were younger and more complicated.[37 51–53 57]

Nine studies investigated the use of a protocolised pathway of care. All reported reductions in length of stay and readmissions. Thirteen additional papers investigated the role of enhanced recovery or same-day discharge pathways with eleven reporting shorter hospital stays without an increase in complications.

Structural Measures: Non-Appendectomy Cohort

Two studies reviewed structural measures in the non-appendicitis cohort. One related to children with intussusception and another to those with abdominal pain of all causes. The specialty of the clinician initially reviewing a child with abdominal pain influenced outcome with those seen by emergency physicians being misdiagnosed less frequently than those seen initially by a paediatrician or paediatric surgeon.[61] Children with intussusception managed in SPCs were also found to have shorter lengths of stay although this difference was not statistically significant.[45]

GREY LITERATURE

The grey literature provided 18 papers highlighting 12 process measures recommended in children having emergency abdominal surgery (Table 2). These articles arose from national and international specialist organisations and consensus statements and can be found in eTable 3. Eleven articles identified fifteen recommended structural measures (Table 2). Most recommendations were consistent with the peer-reviewed literature, however, in contrast to peer-reviewed evidence antibiotics are recommended by some professional bodies for uncomplicated appendicitis.[62 63] Similarly, the grey literature recommends PCA's for children having an open appendicectomy and advises PCA's should also be considered for those having laparoscopic procedures.[64] Additional structural factors identified in the grey literature include having pain, radiology and auxiliary services with paediatric expertise, as well as having policies in place with guidelines for the care of children who cannot be transferred, paediatrician input, provision of critical care, monitoring of patients to identify

deterioration, and a theatre booking system in place which prioritises emergency or high risk cases.

Discussion

This systematic review has evaluated the evidence supporting structures and processes of care which may be considered as quality metrics for paediatric emergency abdominal surgery. These are summarised in Table 3. The majority of evidence available pertains to children presenting with suspected appendicitis, however, some of the identified metrics are also applicable to children presenting with other acute abdominal pathologies. The strength of evidence available is limited with most derived from retrospective observational cohort studies which interrogate administrative databases introducing a degree of bias.[65] Nevertheless, a number of conclusions can be drawn. First, the literature supports measures to improve diagnostic accuracy, including the use of: i) preoperative markers of inflammation, such as WBC and CRP; ii) imaging with US, followed by MRI or CT if inconclusive, in both cohorts, and iii) clinical decision tools. A meta-analysis of studies investigating the diagnostic value of bloods and imaging is beyond the scope of this narrative review, which aims to provide an overview of the level of evidence available for structures and processes in the perioperative pathway of these children. However, the volume of evidence available suggests both bloods and imaging should be undertaken especially when diagnosis is uncertain. In addition, the Pediatric Appendicitis and Alvarado scores are particularly useful in ruling out appendicitis in low risk cases and in determining which patients would benefit from further investigation. Second, implementing a protocolised care pathway ensuring timely access to surgery will likely mitigate poor outcomes associated with delays of over 24 hours for appendectomies and 12 hours for

emergency laparotomies. Third, surgeon and institutional caseload were highlighted as valid structural measures. Finally, current evidence is inadequate to ascertain the impact of specific analgesic regimens, or of specialist care (paediatric surgeon and hospital), on outcome.

Appendicitis is the most common paediatric surgical emergency causing morbidity at scale and cost.[66] Children undergoing emergency laparotomies similarly experience significant morbidity.[67] A lack of consensus on best practice, fuelled by a deficiency in available evidence, results in variation in care and outcomes.[1 4 68] A concerted effort is needed to improve the care delivered to these children. Misdiagnosis presents a particular challenge potentially exposing children to unnecessary surgery. The role of imaging in preventing this has recently been demonstrated in children with SARS-CoV-2.[69 70] Previous reviews have focused on specific aspects of care such as pre-operative investigations or post-operative treatment regimens.[41 71–75] Our novel and extensive systematic review covers the whole patient journey from presentation to discharge producing a comprehensive compilation of relevant evidence-based paediatric-specific structure and process measures, which provide a focus for quality improvement initiatives and highlight areas needing further investigative research.

The influence of surgeon specialisation and hospital setting on outcome is unclear. Whilst some evidence suggests children with suspected appendicitis have better outcomes if admitted under PS rather than GS,[51 52 54] other studies dispute this.[37 42 55 57–60 76] Prolonged length of stay was frequently reported in PS cohorts but these children were often younger and sicker.[37 51 53 57] Despite age and disease severity being independent risk factors for

length of stay and complication rates respectively, adverse events were similar in both groups.[51 53] However, the low incidence of serious complications in these children means studies may be underpowered. Of note, the benefit conferred when managed by a PS is lost once adjusted for volume[42] which suggests differences in outcome may be caseload rather than expertise-driven, and supports the call for minimum annual case numbers.[77 78] Several studies compared PS in specialist centres with GS in non-specialist hospitals, but hospital type is an independent risk factor for outcome. The advantages gained from broader aspects of care in a SPC may have a greater impact than surgical specialty alone.[79] SPCs are more likely to have structures in place which support processes known to influence outcome, including having suitably qualified personnel.[80] Anaesthesia-related complications occur more frequently in hospitals with less specialised support.[44] Perforation rates are also noted to be higher in SPCs, [5 37–40] which may be due to referral bias or the time taken to transfer patients.[6 37] In the USA and UK services are increasingly being centralised with appendectomy rates falling in non-specialist centers,[5 41] despite institutional caseload being an independent risk factor for outcome.[42 47 49]

An additional well-recognised problem in this cohort is that children with an acute abdomen often receive suboptimal analgesia.[19 81] Diagnostic accuracy is not impeded by analgesia and, as such, pain-relief should be administered to children with either suspected appendicitis or other acute abdominal pathologies. The literature available supports a multimodal approach but the role of postoperative opioids is less clear cut as controlled trials have been small using variable analgesic regimens. Meta-analysis was precluded by the heterogeneity in intervention and outcome in the included studies. Placebo usage presents ethical and design issues for acute pain studies and, subsequently, analgesic

recommendations for emergency surgery are often extrapolated from elective surgery studies. Guidelines advocate for the inclusion of PCAs in multimodal strategies post appendectomy[64] but the peer-review literature reports an association between opioid PCAs and prolonged hospital stay. Disease severity is likely to be an important confounder and PCAs remain popular due to their titratable protocols. A similar inconsistency was found in relation to antibiotic administration for simple appendicitis with guidelines identified in the grey literature search calling for their use despite the peer-reviewed literature reporting no benefit.[62 63 82–84] Such discrepancies may be due to guidelines incorporating evidence from very small trials and mixed studies including adults which were both excluded in this review.[64 85] Procedure-specific studies of sufficient size and robust methodology are clearly needed, as is core outcome reporting in clinical trials, enabling meta-analysis to be undertaken.[86] Post-discharge opioid prescribing also needs to be reviewed as the quantity, strength and duration of prescriptions varied significantly.[85 87] Correlation is needed between prescriptions, actual usage and validated pain and patient-satisfaction scores, and in light of the well-described opioid crisis, future recommendations must promote stewardship.[88]

Our review has a number of limitations. Diagnostic accuracy studies can be subject to publication bias. This is particularly true of studies involving paediatric appendicitis.[89] Relying on data-driven analysis when determining the cut-off point required to categorise findings as significant may also be methodologically inadvisable.[90] Evidence may also be hidden in studies that do not test accuracy as their primary objective. For this reason, we used broad search terms, not looking specifically for studies aiming to improve diagnosis,

but rather for any study concerned with this cohort of patients. Nonetheless, it is possible that some relevant papers may have been missed.

Conclusion

This systematic review has synthesised evidence for structures and processes of care which improve outcome in children undergoing emergency abdominal surgery, in particular, those with acute appendicitis. These can be used to benchmark the quality of care being delivered to this patient group and may also be used to inform decisions regarding which areas of practice should be the focus of quality improvement initiatives.

In addition, this review has identified areas of care for which equipoise exists and further work is required. Where possible randomised controlled trials should be conducted, and for measures not suitable for such an approach, multicentre prospective registries are needed. Revision of some existing guidelines may also be considered by professional bodies in light of the summary evidence presented.

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AUTHORS' CONTRIBUTIONS:

LAS: Study design, Data Acquisition, Data Analysis and Interpretation, Drafted Manuscript, Critically Reviewing Manuscript, Approval of Final Version

GS: Data Acquisition, Critically Reviewing Manuscript, Approval of Final Version

MD: Data Analysis and Interpretation, Critically Reviewing Manuscript, Approval of Final Version

SW: Data Analysis and Interpretation, Critically Reviewing Manuscript, Approval of Final Version

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Table 1: Process and structural measures identified in the peer reviewed literature as being associated with outcome in children undergoing appendectomy

Process Measure	Description of Process Measure	Evidence for Process Improving Outcome		Evidence against Process Improving Outcome	
		Frequency of Reporting	Highest Level of Evidence	Frequency of Reporting	Highest Level of Evidence
Use of a diagnostic clinical decision tool/scoring system	Combining clinical features, blood results +/- imaging results	102	1	13	2
Pre-operative Bloods	White Blood Cell count (WBC)	104	2	5	2
	C-Reactive Protein	75	2	3	2
	Procalcitonin	9	2	2	2 or 3
	Platelet count/Mean Platelet Volume (lower count)/Platelet Distribution Width	4	2	2	2
	Fibrinogen	4	2		
	Erythrocyte Sedimentation Rate	3	2		
	Bilirubin	3	2	1	2 or 3
	Interleukin-6	5	2		
	Lymphocyte count (lower count)	4	2	2	2
	Lipopolysaccharide Binding Protein	1	2		
	Neutrophil Gelatinase-Associated Lipocal	1	4		
	Leucine-rich alpha glycoprotein-1	1	2		
	Calprotectin	3	2		
	Leptin	1	4		
	NUCB2 (nucleobindin 2-gene)/nesfatin-1	1	4		
	Urokinase -type plasminogen activator receptor	1	4	1	2
	Neutrophil/Neutrophil %	36	2	1	2
	Neutrophil:lymphocyte	8	2		
	Left shift	4	2		
	Other White Blood Cell count components	2	2	1	2
	Red Cell Distribution Width	1	4		
	Platelet:Lymphocyte	1	4		
	Mean Corpuscular Volume	1	4		
	Tumour Necrosis Factor - alpha (TNF-alpha)	1	2		
	D-Dimer	1	2	5	2
	Hyponatraemia	1	2		
	Miscellaneous (individual tests and biopanels)	21	2		
Pre-operative Urine Sample	Various Urinary Markers	4	2		
Pre-operative Saliva Sample	Irisin	1	4		
Pre-operative Imaging	Ultrasound	79	2	6	2
	CT	28	2	6	2
	Point of care US (POCUS)/clinician performed	9	2	1	2
	MRI	16	2		

	Echnetium-99m hexamethylpropylene amine oxime-labelled WBC scans	1	2		
	Imaging Protocol	6	2		
Pre-operative Analgesia	To be given (morphine/oxycodone)	1	1	1	1
Pre-operative Antibiotics	Administration in simple appendicitis			3	1
	Pre-op antibiotics in complicated appendicitis	1	2		
	Intra-operative antibiotic powder in addition to IV antibiotics	1	4		
	Administration within 6 hours of incision	1	2		
Time to Surgery	Surgery required within 24 hours of presenting (within 12 hours)	16 (4)	2	4	2
Post-op Analgesia plan	Use of NSAID (Diclofenac/Ketorolac)	5	1		
	Use of paracetamol (10mg/kg)			1	1
	Post op intermittent opioid dosing cf. PCA or continuous infusion			1	2
	Post op opioids			3	2
	Ketamine PCA			1	1
	Local anaesthetic in wound of open appendicectomies	1	1	1	1
	Local anaesthetic spray into abdomen			1	1
	Rectus Sheath Blocks	1	2		
	Use of gabapentin	1	2		
	Analgesia Pathway	1			
Post-op antibiotics:	Simple appendicitis			1	1
complicated	Complicated appendicitis	1	2		
simple	Short course with conversion to oral post complicated appendicitis (including for discharge)	10	1	1	4
	Discharge home with any antibiotics			1	2
Structural Measure	**Description of Structural Measure**	**Evidence for Structure Improving Outcome**		**Evidence against Structure Improving Outcome**	
		No. of Articles	**Highest Level of Evidence**	**No. of Articles**	**Highest Level of Evidence**
Type of Hospital Providing Care	Specialist Paediatric Surgery Centre vs General Hospital	11	2	7	2
	Teaching Hospital vs Non-Teaching Hospital			2	2
Hospital Caseload Volume		4	2	1	2
Surgeon Caseload Volume		1	2		
Location of Hospital	Urban vs Rural	1	2	1	2
Specialty Team Responsible for this Group	Specialist Paediatric Surgeon vs General Surgeon	3	2	8	2
	Specialist Paediatric Surgeon vs Trauma Surgeon			1	2
Perioperative pathway of care	Generalised perioperative care pathway	9	2		
	Enhanced recovery/Same day discharge	12	2	1	2

Key: Computed Tomography (CT); Magnetic Resonance Imaging (MRI); Non-Steroidal Anti-Inflammatory Drugs (NSAIDs); Patient-Controlled Analgesia (PCA)

Table 2 – Process and structural measures identified in the grey literature advocated to improve outcome in children undergoing emergency abdominal surgery

Process Measure	Description of Process Measure	Evidence for Process Improving Outcome	
		No. of Articles	Highest Level of Evidence
Transfer to specialist centre	Transfer of any child with intussusception	1	5
	Transfer in a timely manner in accordance with guidelines	3	5
	Patient should be handed over within 15 mins of arrival	1	5
	Child < 5 years old with suspected peritonism requires urgent referral to specialist paediatric surgeon	1	5
	Adequately resuscitated prior to transfer	1	5
Time to Initial Assessment	Within 15 mins	2	5
By whom initial assessment was conducted	By attending/consultant if re-presenting within 72 hours	1	5
	By attending/consultant surgeon if < 5 years old	1	5
	By attending/consultant surgeon if seriously unwell	1	5
Pre-operative Analgesia	To be given within 20 mins of arrival	2	5
Pre-operative Intra-venous Fluids	Emergency patients awaiting surgery	1	5
	When diagnosis of intra-abdominal infection is suspected	1	5
Antibiotics	Administration within one hour if high risk criterion	1	5
	Antibiotics for all even uncomplicated appendicitis	2	5
	Antibiotics for uncomplicated appendicitis should be narrow spectrum and should be discontinued within 24 hours	1	5
	Duration of antibiotics for appendicitis should not be longer than 48hrs	1	5
	Antibiotics for all colorectal procedures	1	5
Use of Clinical Decision Tools	Initial assessment should be facilitated by clinical scoring systems	1	5
Pre-op imaging	Imaging should be performed for all children especially < 3 years old when the diagnosis is not certain.	1	5
	Non-radiating imaging should be preferred in children	3	5
	US to confirm but not exclude diagnosis of appendicitis	1	5
	CT can be used to confirm or exclude diagnosis of appendicitis	1	5
	Further diagnostic imaging is unnecessary if obvious peritonitis and plan for immediate surgery	1	5
	If negative imaging, patients should be followed up at 24 hours	1	5
Pre-operative Anaesthetic Review	Pre-op review by an anaesthetist	1	5
Time to Surgery	Within 2 hours for most life-threatening	1	5
	Emergency surgical conditions not requiring immediate intervention should not wait > 12 hours from decision to operate/as soon as feasible	2	5
	Perforated appendicitis should undergo immediate intervention to provide adequate source control	1	5
Post op Clinician Review	By a attending/consultant surgeon more than once every 24 hours, 7 days a week	1	5
	On general intensive care unit (ICU) review by senior paediatrician every 12 hours	1	5
Post op Analgesia plan	Laparotomy – opioids as continuous infusion, NCA/PCA, +/- epidural	1	5
	Open appendectomy – PCA + NSAIDs	1	5

		Lap appendectomy – LA in port sites and may need as above for at least first 24 hours	1	5
Structural Measure		**Description of Structural Measure**	**Evidence for Structural Measure**	
			No. of Articles	**Highest Level of Evidence**
Transfers		Hospital teams should have the capacity to undertake transfers of these patients if it is time critical	1	5
Capacity to provide critical care		Fully staffed High Dependency Unit on site and formal arrangement for Paediatric Intensive Care admission There should be facilities to provide short term critical care prior to transfer	1 1	5 5
Booking of Surgery		System in place which prioritises emergency/high risk cases	2	5
Surgical Operating Experience		Surgeons operating on children should have ongoing experience	1	5
Policies / Guidelines in place should include those relating to:	Children who cannot be transferred	To support surgeons and anaesthetists undertaking life-saving interventions in children who cannot be transferred	3	5
	Paediatrician input	All sites should have 24-hour cover by attending/consultant paediatrician who can arrive within 30 mins and does not have responsibilities at other hospital sites	3	5
	Monitoring of the surgical patient	Care relating to the surgical patient should include actions to prevent / prepare for deterioration Paediatric Early Warning System (PEWS) should be used	1 2	5 5
	Sepsis	Sepsis policy including antibiotics in the first hour	1	5
	Anaesthesia	Guidelines in place for the anaesthetist on preparation of a child for undergoing a general anaesthetic Local policy in place detailing when in the operating room attending/consultant anaesthetist presence is needed Anaesthesia for life-saving procedures should ideally be managed by a team of two anaesthetists Policy indicating the annual minimum case volume load for anaesthetists looking after children	1 1 1 1	5 5 5 5
Provision of a Pain Service		There should be a fully resourced pain service covering the needs of children Pain management policy in place for children undergoing anaesthesia	2 1	5 5
Access to Radiology		Timely access to imaging, interventional radiology and specialist paediatric radiology advice	2	5
Access to Auxiliary Services		24-hour access to pharmacy, pathology and physiotherapy services to support the care of children	3	5
Participation in Clinical Networks		Non-specialist and specialist centres should participate in multidisciplinary networks for surgery and anaesthesia which agree standards of care and formulate care pathways for common emergency surgery	1	5
Review of Service		Standards should be audited and participation in national audits encouraged, and information fed back to frontline staff Morbidity & Mortality meeting if death within 30 days of surgery Patient reported outcomes should be reported annually Review of service should specifically include: • Time between admission/decision to operate and operation time • Length of Stay • Morbidity • Mortality • Surgical transfers	1 2 1 1	5 5 5 5

	• Untoward incidents • Unplanned re-admissions • Unplanned admissions to critical care		
Key: Ultrasound (US); Computed Tomography (CT); Nurse-Controlled Analgesia (NCA); Patent-Controlled Analgesia (PCA); Non-Steroidal Anti-Inflammatory Drugs (NSAIDs); Local Anaesthetic (LA)			

Table 3: Summary of Evidence-Based Quality Metrics		
		Quality Metric
Process	Pre-operative investigations	Blood testing (markers of inflammation including WBC and CRP) and US imaging should be used especially in cases where there is diagnostic uncertainty.
	Clinical Decision Tools	CDTs such as the Paediatric Appendicitis and Alvarado Scores should be used to improve diagnostic accuracy in children with suspected appendicitis. Tools should combine clinical features, blood tests +/- imaging.
	Time to Surgery	Suspected acute appendicitis: Children should receive their surgery within 24 hours of presenting Non-appendicitis acute abdomen: Children with an acute abdomen suspected secondary to other pathologies should receive their surgery within 12 hours of presenting to hospital
	Analgesia	Pre-operative: a pain assessment should be undertaken within 20 mins of presentation and analgesia including intravenous opioids should be administered as needed. Intra-operative: analgesia plans should include regional anaesthesia techniques such as rectus sheath blocks (or similar), or local anaesthetic wound infiltration. Post-operative: analgesia should be multimodal and should include paracetamol, NSAIDs and opioids. Children should only be discharged home with opioids when clearly indicated and prescriptions should be for the minimum necessary strength, quantity and duration.
	Antibiotics	Children with complicated appendicitis should receive antibiotics for 5-7 days with an early transition from intravenous to enteral antibiotics.
Structure	Caseload	Institutions and individual surgeons should record and periodically review their caseloads to ensure that they maintain sufficient current experience in operating on children.
	Perioperative care pathways	Care pathways should be used for children presenting with an acute abdomen including enhanced recovery where appropriate.

Figure Legend:

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) Flow Diagram.