

Pre-operative Imaging Avoids Unnecessary Surgery for Suspected Acute Appendicitis

Gavin Nair^{*}, James Virgin, Tim Kenyon-Smith, Bev Thomas, Karolina Juszczuk, Hidde Kroon, Paul Hollington

Colorectal Unit, Department of General Surgery, Flinders Medical Centre, Adelaide, Australia

Email address:

Gavin.Nair@sa.gov.au (G. Nair)

^{*}Corresponding author

To cite this article:

Gavin Nair, James Virgin, Tim Kenyon-Smith, Bev Thomas, Karolina Juszczuk, Hidde Kroon, Paul Hollington. Pre-operative Imaging Avoids Unnecessary Surgery for Suspected Acute Appendicitis. *Journal of Surgery*. Vol. 9, No. 1, 2021, pp. 10-15.
doi: 10.11648/j.js.20210901.12

Received: December 15, 2020; **Accepted:** December 28, 2020; **Published:** January 22, 2021

Abstract: *Background:* The decision to perform an appendicectomy is traditionally based on clinical findings. This approach, however, results in high rates of negative (non-inflamed) appendicectomies with procedure morbidity associated. Therefore, some consider a negative appendicectomy to be a complication since surgical morbidity could have been avoided. The aim of this study was to evaluate the effect of preoperative imaging on the negative appendicectomy rate in case of suspected appendicitis. *Methods:* The prospectively collected database for all patients who had undergone acute surgery for a suspected appendicectomy, with or without preoperative imaging, was analysed over a 5-year period. Patient and treatment characteristics, histopathology and postoperative outcomes were recorded and analyzed. *Results:* A total of 2,070 patients were included, 848 (41%) with preoperative imaging (CT, ultrasound or MRI) and 1,222 (59%) without. Imaged patients were older and suffered from more comorbidities. The negative appendicectomy rate was 19.2% (n=235) for the non-imaged patients, and 12.4% (n=105) for imaged patients ($p<0.0001$). When preoperative imaging was performed, a CT-scan was most accurate to diagnose appendicitis correctly compared to ultrasound (93.6 vs. 30.2%, $p<0.0001$). Median hospital stay was 3.2 days in the imaged group compared to 2.1 days in the non-imaged group ($p=0.171$). *Conclusion:* Preoperative imaging significantly reduces the negative appendicectomy rate. In this time of modern imaging modalities readily available, it is recommended to perform preoperative imaging in case of suspected acute appendicitis to avoid unnecessary surgery and associated morbidity.

Keywords: Acute Appendicitis, Negative Appendicectomy, Emergency Surgery, Preoperative Imaging, Complications

1. Introduction

An acute appendicitis (AA) is one of the most common causes of an acute abdomen. [1]

Traditionally, many surgeons decide to perform an appendicectomy based on clinical presentation, physical examination and inflammatory marker level in the blood results. This approach, however, can lead to negative appendicectomy (NA) rates as high as 20%, meaning that one in five patients is unnecessarily exposed to the perioperative risks and morbidity associated with the surgical procedure. [2] Moreover, a NA is associated with significantly higher morbidity and mortality rates when

compared to patients who have surgery for an AA. [3, 4] Therefore, Anderson et al. concluded that accurate diagnosis of the acute abdomen plays an important role in preventing this morbidity.

Recent studies that have looked into performing standard preoperative imaging, have shown that its use for patients with suspected appendicitis was associated with a reduction in NA's, while the delay to surgery, caused by the preoperative imaging, did not increase the perforated appendicitis rate. [5, 6] Based on these results, some Surgical Colleges around the world have incorporated standard imaging into their appendicitis guidelines. In Australia, however, the guidelines only suggest for imaging to be done when there is doubt of the diagnosis. Particularly in our

centre, the standard protocol is for imaging only when deemed necessary by the surgeon.

At Flinders Medical Centre (FMC), a tertiary teaching hospital in South Australia, the protocol states that preoperative imaging is not standardly performed for patients with a suspected appendicitis. This can however be considered upon the discretion of the treating surgeon in case of diagnostic doubts. (Appendix A) Therefore, the aim of the current study was to evaluate the effect of preoperative imaging on the NA rate in our hospital in patients with a suspected appendicitis.

2. Patients and Methods

This is a single-centre analysis of the prospectively collected database of the Department of General Surgery at FMC, a tertiary teaching hospital in Adelaide, Australia, over a 5-year period from January 2013 to December 2017. All patients, ≥ 13 years, who underwent emergency surgery for a suspected acute appendicitis were included.

Our hospital's appendicitis protocol (appendix A) states that from patients who present to the Emergency Department (ED) with a suspected appendicitis, a history is taken and then undergo clinical examination, and blood and urine work-up. Preoperative imaging is considered in case of an atypical history, persistent symptoms or at the discretion of the admitting surgeon. A CT-scan is the preferred imaging modality. In case gynecological pathology is also considered, an ultrasound is preferred in view of radiation. If an acute appendicitis is clinically diagnosed, patients are administered analgesia, intravenous fluids and IVAB (ampicillin 1,000mg, metronidazole 500mg and gentamicin 5mg/kg), and are booked for an emergency appendectomy. A laparoscopic appendectomy is the preferred approach.

The following data were collected: age, gender, comorbidities (Charlson index), preoperative performed and type of preoperative imaging modality, surgical approach (laparoscopic or open), conversion rates, AA or non-inflamed appendix according to the operation report and alternative pathology found upon surgery, histopathology report stating either an AA or a non-inflamed appendix, postoperative complications such as surgical site infection, intra-abdominal collection and pneumonia, and postoperative complications according to the Clavien-Dindo scale, length of hospital stay, and 30-day readmission rates. A surgical site infection was defined as redness of the skin and/or wound breakdown, requiring laying open of the wound and/or prolonged antibiotic treatment. An intra-abdominal collection was defined as a collection detected on postoperative imaging or during reoperation requiring prolonged antibiotic treatment and/or drainage. Data not available from our database were supplemented from patient records.

Patients were divided into two groups: those who had no imaging before the appendectomy and those who did have preoperative imaging performed. The primary outcome

measure was the negative appendectomy (NA) rate in patients with suspected appendicitis who did or did not undergo preoperative imaging. Secondary outcomes were complications rates, length of hospital stay and readmission rates.

The Chi²-test was used for comparison of frequency distributions and the Mann-Whitney U test was used for the nonparametric variables. Data were analyzed using GraphPad Prism Version 8 (GraphPad software Inc., San Diego, CA, USA) and SPSS version 26 (SPSS Inc., Chicago, IL, USA). A significant difference was assumed for a probability value of <0.05 .

3. Results

A total of 2,070 patients who underwent appendectomy as an emergency procedure during the study period were included (Table 1): 848 (41%) underwent preoperative imaging (CT-scan, ultrasound or MRI-scan) and 1,222 (59%) did not. Imaged patients consisted of more females compared to the non-imaged patients (61.9 vs. 45.6%, $p<0.0001$), and were older with a median age of 43 years (range 13-91 years) compared to 27 years (range 13-85 years) for non-imaged patients ($p<0.0001$). Imaged patients suffered from more comorbidities: 248 patients suffered from one or more comorbidities compared to 132 in the non-imaged group ($p<0.0001$). In the imaged group, CT-scan was most frequently performed in 675 patients (79.6%), while 159 had an ultrasound (18.7%) and 14 patients had an MRI (1.7%).

Open surgery was performed in 59 patients (7.0%) of the imaged group and in 20 patients (1.6%) of the non-imaged group ($p<0.0001$; Table 2). Operative diagnosis of an appendicitis was recorded by the operating surgeon in 777 patients (91.6%) of the imaged group and in 1,088 of the non-imaged patients (89.0%, $p=0.06$). In 53 of the imaged patients (6.3%) an alternative intra-operative diagnosis was found, while in 18 (2.1%) no intraoperative diagnosis could be made. This was in the case in 102 (8.4%) and 32 (2.6%) of the patients in the non-imaged group, respectively. Upon histopathologic examination, appendicitis was confirmed in 783 (87.6%) of the imaged patients, while in 105 (12.4%) a NA was performed as the appendix was not inflamed. In the non-imaging group, this was the case in 987 (80.8%) and 235 (19.2%) patients, respectively ($p<0.0001$). Median hospital stay was 3.2 days in the imaged group (range 1-15 days) and 2.1 days in the non-imaged group (range 1-10, $p<0.0001$). Forty-seven of the imaged patients were readmitted within 30 days and 51 patients in the non-imaged group (5.5% vs. 4.2% respectively, $p=0.17$).

In case a CT-scan was performed, it was more accurate in diagnosing an appendicitis correctly compared to an ultrasound upon histopathological diagnosis (93.6% vs. 30.2%, $p<0.0001$; Table 3).

Table 1. Baseline characteristics of patients with a suspected appendicitis who either had preoperative imaging or no imaging performed.

	Preoperative imaging n=848	No preoperative imaging n=1,222	p-value
Gender (%)			
Male	323 (38.1)	665 (54.4)	<0.0001
Female	525 (61.9)	557 (45.6)	
Age in years, median (range)	44 (13-91)	27 (13-85)	<0.0001
Number of major comorbidities per patient (%)			
0	600 (70.8)	1,090 (89.2)	<0.0001
1	128 (15.1)	92 (7.5)	
2	61 (7.2)	26 (2.1)	
>2	59 (6.9)	14 (1.2)	
Diagnostic imaging modality used (%)			
CT			N/A
Ultrasound	675 (79.6)		
MRI	159 (18.7)		
None	14 (1.7)	1,222 (100)	

N/A: non applicable

Table 2. Perioperative and histopathological outcomes.

	Preoperative imaging n=848	No preoperative imaging n=1,222	p-value
Surgical approach (%)			
Laparoscopic	789 (93.0)	1202 (98.3)	<0.0001
Open	59 (7.0)	20 (1.7)	
Appendicitis clinically described during surgery (%)			
Yes	777 (91.6)	1088 (89.0)	0.06
No	71 (8.4)	134 (11.0)	
Other diagnoses made during surgery (%)			
Mesenteric adenitis	13 (1.5)	22 (1.8)	<0.0001
Ovarian cyst	6 (0.7)	13 (1.0)	
Neoplasm	8 (0.9)	12 (0.9)	
Intestinal perforation	4 (0.4)	17 (1.4)	
Meckel's diverticulum	7 (0.8)	8 (0.6)	
Other	15 (1.7)	30 (2.4)	
No diagnosis made upon surgery	18 (2.1)	32 (2.6)	
Appendicitis on histopathology? (%)			
Yes	743 (87.6)	987 (80.7)	
No (NA)*	105 (12.4)	235 (19.2)	
Complication (%)			
yes	77 (9.1)	62 (5.1)	0.0005
no	771 (90.9)	1160 (94.9)	
Postoperative complications according to the Clavien-Dindo scale (%)			
1	13 (1.5)	12 (0.9)	
2	41 (4.8)	36 (2.9)	
3a	11 (1.3)	9 (0.7)	
3b	4 (0.4)	2 (0.1)	
4a	5 (0.6)	2 (0.1)	
4b	2 (0.2)	-	
5	1 (0.1)	1 (0.1)	
Hospital stay in days, median (range)	3.2 (1-15)	2.1 (1-10)	<0.0001
Unplanned 30-day readmission (%)			
Yes	47 (5.5)	51 (4.2)	
No	801 (94.5)	1171 (95.8)	0.17

*NA negative appendicectomy

Table 3. Comparison of CT scan and other imaging (Ultrasound/ MRI).

	CT scan, N=675	Other imaging, n=159*	P-value
Diagnosis (%)		Ultrasound, 159/848 (18.7)	
Appendicitis	632 (93.6)	48 (30.2)	<0.0001
No Appendicitis	43 (6.37)	111 (69.8)	
Imaging (%)		MRI	
Diagnosis (%)		14/848 (0.23)	
Appendicitis		14 (100)	
No appendicitis		-	
Histopathological diagnosis of appendicitis (%)			
Yes	614 (90.9%)	129 (74.6%)	<0.001
No	61 (9.03%)	44 (25.4%)	

4. Discussion

In this high-volume single-centre experience of appendicitis diagnosis and treatment, we found that preoperative imaging significantly reduces the negative appendectomy rate resulting in decreased complications. In our center, we found that CT scan was the most frequently used modality, followed by ultrasound and then MRI. CT scan was more frequently used in patients that were older with more comorbidities compared to clinical assessment alone.

In our study, the imaged group of patients comprised of more female and elderly with more comorbidities. This was mainly due to the fact female patients received imaging earlier to rule out gynaecological pathology. CT scan was the most used imaging modality for a number of reasons, ease of availability compared to ultrasound scans that required a sonographer and increased diagnostic sensitivity and specificity. The diagnostic accuracy of CT scan in our study was 94% which is comparable with other studies [7-9].

Diagnostic imaging is increasingly used in this current era for investigation of patients with abdominal pain particularly in cases of suspected appendicitis and has reduced NA rates and complication rates. [10, 11] In countries like the Netherlands, mandatory pre-operative imaging has been implemented; in a large multinational trial, the NA rates were seen to reduce for 15% to 3.3% in patients receiving imaging pre-operatively. The odds for negative appendectomy without preoperative imaging was 3.7 (CI 3.0-4.4), even after adjusting for age, sex and white cell count. These results are promising and warrant a review of the evidence to evaluate its implementation. [12, 13] The NA rates in our centre was 12% on histopathology which is comparable with other studies. A meta-analysis including 22 articles with 2,643 patients performed by Yu et al. in 2005 showed a negative appendectomy rate of 10.7% in patients with suspected appendicitis when using ultrasound; in patients who did not get ultrasound, the rate was between 10 and 20%. [14] Guss et al. reported a decrease in negative appendectomy rate from 15.5 to 7.9% since the introduction of CT scanning in patients with suspected appendicitis. [15]

Complication rates of appendectomies remained around 10% and were remarkably similar between positive and negative cases. Common complications include wound infection, abscesses, or hospital-acquired infections- these

can be reduced by avoiding unnecessary surgery. [16, 17] The increase use of imaging also in most literature did not result in a worst outcome for patients with perforated appendicitis. [18, 19]

We have shown that the use of imaging improves the treatment outcome of patients with suspected appendicitis. There have been ample controversy about the modality of imaging. Studies published previously comparing the better diagnostic performance of CT scan compared to ultrasound. Ultrasound does not always offer a definite diagnosis and requires additional modalities such as a CT scan or MRI. CT scan offers higher sensitivity and specificity of 84% and 99% respectively and has been shown in some studies to reduce the rate of NA from 13% to 5%. [20] The Surgical Care Outcomes and Assessment Program (SCOAP) in America showed a significant reduction in NA rates compared to Ultrasound which analysed a dataset of 20,000 patients across 60 hospitals. [13] In our study, we did not have sufficient number of patients from the MRI cohort however, all 14 patients had confirmed diagnosis of appendicitis. MRI scans are far less accessible in hospital making it not the best modality. In our centre, we reserve MRI scans for patients that are pregnant. Some of the limitation of CT scan include concerns regarding dose radiation which in studies have been shown to be 10-20 mSv which is equal to 500-1000 chest radiography although there is a variation of 5-32mSv between centres. [21, 22] In a study comparing high and low appendicitis CT doses (5.2 mSv vs 1.4 mSv in males and 7.1 mSv vs 2.2 mSv in females) no significant difference was found ($P>0.05$) [23]. Limitation with Ultrasounds include lower sensitivity of 55% and specificity of 94% mainly because it is operator dependent with patient habitus having an impact on the quality of images. [24]

In our study, we found that surgeons' opinion during surgery of appendicitis were less accurate than histopathology 89% of surgeons intraoperatively diagnosed appendicitis with 80% confirmed on histopathology in the non- imaged group. Some appendixes may look thickened, but are not really inflamed, which could account for why the non-imaging group showcased a larger difference between the intra-op and histopathology findings. Imaging prevents those with a thicker appendix, but no inflammatory changes, to go to theatre.

Limitations of the study include that it was retrospective and not a randomised controlled trial that was done in a single centre. The cohort of patients was adequate for

sampling size. There was an unequal distribution of patients with more females and elderly patient with more comorbidities in the imaging group. This result in a bias as there is more reason to perform imaging in the older population with more comorbidities as there is a higher chance to prevent surgery if there was an alternative diagnosis. Also the decision to perform surgery was biased as it was a clinical decision and not based on a protocol.

This study should pave the way for more prospective study to further understand the role of Pre-operative imaging in acute appendicitis, should all patients undergo some imaging in case of suspected appendicitis and should this be reflected in the guidelines. Should we train more sonographers to perform ultrasounds to look for appendicitis as this is not current practice in the adult population in our centre.

5. Conclusion

In conclusion, our study demonstrates that NA rates can be reduced significantly with the use of preoperative imaging. CT scans in particular have been shown to significantly more reduce the rates of NA without increasing the morbidity or the patient. Considering the increase morbidity of patient with NA that are operated on, the risk benefit should be considered thoroughly by the treating surgeon. The clinical potential of this has been demonstrated and offers a solution to unnecessary operations and expenditure.

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