

Patient factors influencing the effect of surgeon-performed ultrasound on the acute abdomen

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Abstract

Purpose To evaluate the effect of surgeon-performed ultrasound on acute abdomen in specific patient subgroups regarding the diagnostic accuracy and further management.

Methods Eight hundred patients attending the emergency department at Stockholm South General Hospital, Sweden, for abdominal pain, were randomized to either receive or not receive surgeon-performed ultrasound as a complement to routine management. Patients were divided into subgroups based on patient characteristics, symptoms or first preliminary diagnosis set at the emergency department before randomization. Outcomes measured were diagnostic accuracy, admission rate and requests for further examinations. Timing of surgery was evaluated for patients with peritonitis.

Results Increased diagnostic accuracy was seen in patients with body mass index > 25, elevated C-reactive protein, peritonitis, age 30–59 years and/or upper abdominal pain. Decreased need for further examinations and/or fewer admissions were seen in all groups except in patients with a preliminary diagnosis of appendicitis. Among patients with non-specific abdominal pain, admission frequency was decreased with 14% when ultrasound was used ($P = 0.007$).

Among patients with peritonitis, requiring surgery, 61% in the ultrasound group were admitted for surgery directly from the emergency department compared to 19% in the control group.

Conclusion In different ways, surgeon-performed ultrasound is helpful for the majority of patients admitted to the emergency department for abdominal pain. Taking into account other shown benefits and the lack of adverse effects, we find the method worth consideration for routine implementation.

Keywords Ultrasonography · Abdominal pain · Surgery · Body mass index · Appendicitis · Gallbladder disease

Introduction

Abdominal pain is a common reason to seek medical care at the emergency department (ED) [1, 2]. For about half of the patients, some sort of radiological examination is requested [3–5]. It is therefore important to evaluate different management strategies at the ED for improvement of diagnostic accuracy to optimize patient care and the use of health care resources.

It is possible to perform ultrasound (US) examinations bedside and they do not have any known side effects [6], which makes them suitable for the use at the ED. Bedside abdominal US performed at the ED, as well as computer tomography (CT) examination at an early stage, has been shown to increase diagnostic accuracy as well as diagnostic certainty when a patient presents with abdominal pain of unknown origin [7–11]. Abdominal ultrasound is known to increase diagnostic accuracy for patients presenting with upper right abdominal pain [12–14]. The results for diagnosing appendicitis with the help of US are still

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controversial and the diagnostic accuracy is operator dependent [15]. Several studies, though, have shown good results of US for diagnosis of appendicitis [16–18].

An immediate ultrasound examination may not only increase diagnostic accuracy, but also provide additional information making it easier for the surgeon to determine the patient's need for operation at an earlier stage [4, 13].

The aim of this study was to determine the effect of surgeon-performed US bedside at the ED, based on several patient characteristics, on diagnostic accuracy and further management of patients admitted to the ED for abdominal pain.

Methods

The study was conducted between February 2004 and June 2005 at the ED of Stockholm South General Hospital, a public general hospital with a catchment area of about 600,000 inhabitants.

Nine surgeons with at least 2 years experience of surgery after completing internship participated in the study. The surgeons attended a 1-week course given by a specialist in ultrasound examination followed by 3 weeks of training in the radiological department in abdominal ultrasound, under the guidance of an ultrasound specialist. The surgeons were trained in detecting the following disease states: gallbladder stones, cholecystitis, wide bile ducts, hydronephrosis, abdominal aortic aneurysms, ovarian cysts, free abdominal fluid, pleura fluid collections, large abdominal masses, inflamed appendix, diverticulitis, intestinal obstruction, liver disease and large kidney stones.

All patients, 18 years or older, admitted to the emergency ward for abdominal pain were eligible to participate in the study. Exclusion criteria were pregnancy, previously diagnosed abdominal condition, acute conditions needing immediate care, inability to communicate with the investigator, drug or alcohol addiction and dementia.

Eight hundred patients were enrolled for the study. After inclusion, the patients were examined by the study surgeon. Medical history was taken, and clinical examination and routine laboratory testing were performed. The study surgeon set a first preliminary diagnosis and then opened a sealed randomization envelope randomizing the patient to US or not. If randomized to the US group, the examination was performed with one out of two handheld, 2.5–5 MHz or 4.3–6 MHz, curved array transducers (B–K medical, Denmark, Hawk 2102, transducers type 8665 and 8802) screening the entire abdomen. The two groups were subsequently managed

according to clinical routine as decided by the study surgeon.

The correct diagnosis was defined as the final diagnosis set by a senior surgeon 6–8 weeks after the patient had entered the study, based on information in the patient records. The senior surgeon was not aware of the preliminary diagnosis set by the surgeon at the ED. The final diagnosis was then compared with the preliminary diagnosis, with or without US examination.

All information on the patients collected in the ED was entered by the study surgeon on a case report form. Additional data about the patients who were admitted to the hospital for in-patient care were collected from the patient records and entered on a complementary case report form, designed for the admission period.

We examined selected outcomes in different subgroups based on body mass index (BMI), age, level of C-reactive protein (CRP), signs of peritonitis, symptoms predictable for appendicitis (pain and tenderness in lower right abdomen), gallbladder disease (pain and tenderness in upper right abdomen) and first preliminary diagnosis of appendicitis, gallbladder disease or non-specific abdominal pain set at the ED before randomization. The outcomes analyzed were diagnostic accuracy, admission rate and amount of further examinations ordered at the ED [US examinations and computer tomography (CT) scans from the radiological department or any other further examinations]. In the BMI groups, we also examined level of difficulty and reliability of the US examination as assessed by the examining surgeon. For patients with signs of peritonitis, we also analyzed the timing of the decision about surgery.

Statistical analysis

Chi-square test was used to compare groups regarding diagnostic accuracy, amount of requested complimentary examinations and hospital admission. If surgery was needed, we also compared the groups regarding when the decision on whether or not to perform surgery was taken. The results were regarded as significant if *P* was less than 0.05, two-tailed. All analyses were performed according to intention to treat using SPSS version 16.0.

The sample size was calculated on the basis of the primary outcome of the study, diagnostic accuracy, presented in an earlier article [10].

Ethical considerations

The patients received oral and written information from the study surgeon, and were included after informed consent. The study was approved by the Institutional Review Board

at Karolinska Institutet, Stockholm, Sweden. The study has been registered in ClinicalTrials.gov ID NCT00550511.

Results

Participation and background data

Among the 800 patients randomized in the study, one patient was missing due to loss of the study protocol and eight patients in each group did not fulfill the inclusion criteria. Thus, 392 patients in the ultrasound group and 391 patients in the control group were eligible for statistical analysis (Fig. 1). Two patients in the ultrasound group and one patient in the control group switched groups.

The baseline characteristics for the study subjects are shown in Table 1.

What benefits were shown in the subgroups?

Table 2 summarizes the benefits of bedside US in the different evaluated subgroups. Some sort of benefit was seen in all groups except among the patients with a preliminary first set diagnosis of appendicitis, where the intervention groups were equal regarding all outcomes.

Age

In the age group of 30–59 years, diagnostic accuracy was higher and requests for CT examinations were fewer

Fig. 1 Study flow chart

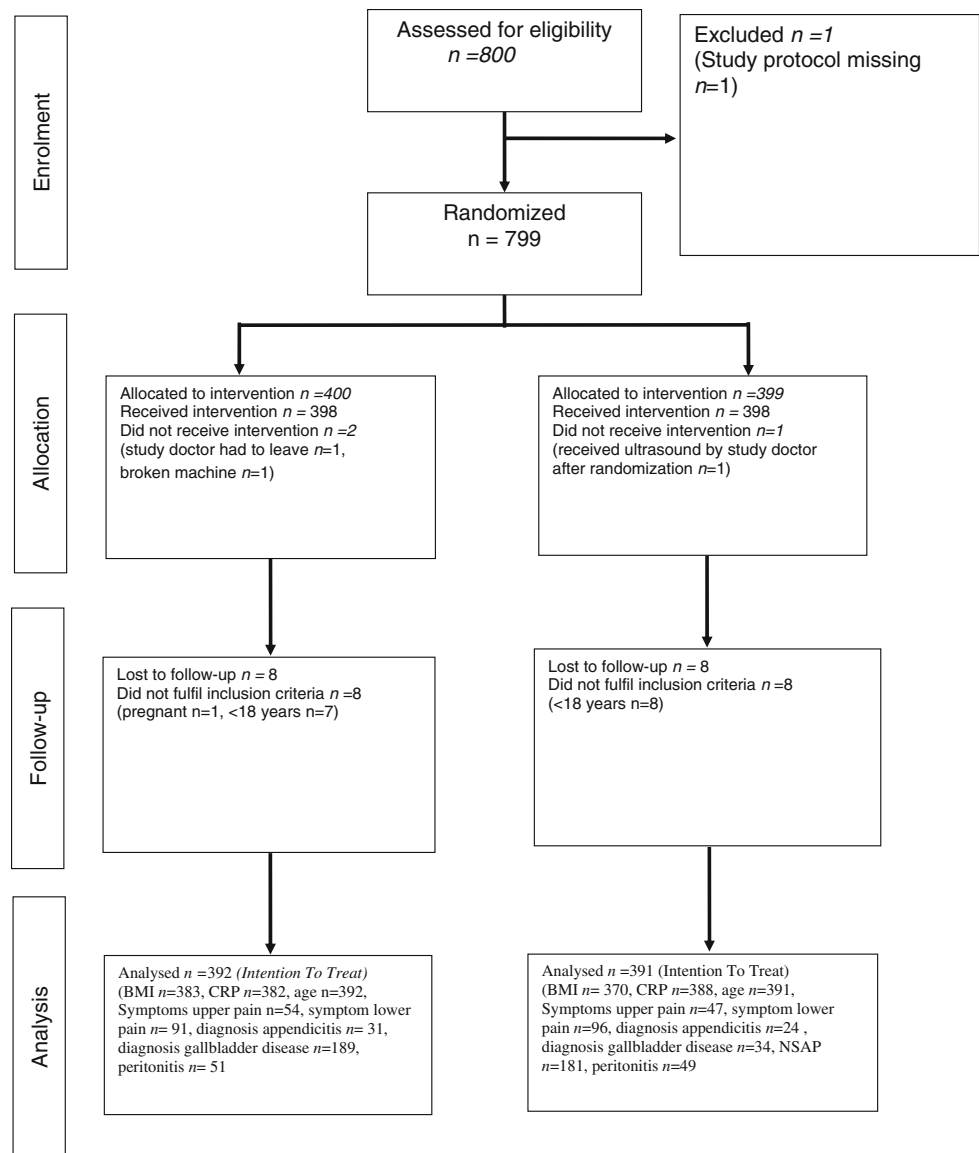


Table 1 Baseline characteristics of patients with abdominal pain at the ED

Characteristics	Ultrasound (<i>n</i> = 392)				Non-ultrasound (<i>n</i> = 391)			
	Mean	SD	<i>n</i>	%	Mean	SD	<i>n</i>	%
Age	47	20			48	19		
Height	172	9			172	10		
Weight	73	16			73	16		
BMI (body mass index)	24.8	4.5			24.8	4.3		
Gender								
Male			160	40.8			171	43.7
Female			232	59.2			220	56.3
Abdominal related comorbidity			76	19.4			78	19.9
Comorbidity related to heart or diabetes			66	16.8			74	18.9
History of abdominal malignancy			6	1.5			12	3.1
History of other malignancy			11	2.8			14	3.6
Other comorbidity			132	33.7			123	31.5
Admission for abdominal pain within 1 year			124	32.0			137	35.3
Referral for admission			92	24.4			126	32.9
Duration of pain								
0–8 h			44	14.8			43	14.4
8–24 h			99	33.2			97	32.4
>24 h			147	49.3			151	50.5
Cannot answer			8	2.7			8	2.7
Affected general condition			90	23.3			74	19.1
Tenderness			338	86.4			347	89.2
Rigidity			51	13.1			49	12.6
Palpable mass			23	5.9			29	7.5
Actual VAS (of pain) ^a	4.3	2.8			4.4	2.6		
Maximal anamnestic VAS (of pain) ^a	7.6	2.6			7.6	1.8		
Temperature	37.0	0.8			37.0	0.7		

^a VAS (of pain) = Visual Analogue Scale (scale 0–10, 0 represents no pain at all, 10 represents unbearable pain)

among the patients examined with US. In all age groups, fewer complementary radiological US examinations were ordered in the US group as well as fewer further examinations except from the oldest group (Table 3).

Body mass index

In the group with BMI 25 or more, the diagnostic accuracy was higher and there were fewer requests for computer tomography examinations if the patient had been examined with US. The frequency of complementary US examinations at the radiological department or other further examinations was lower in the US group regardless of BMI (Table 4).

There was a significant difference in frequency of difficulty in performing US, when comparing patients with BMI 25 or more with BMI less than 25 (59 vs. 23%, $P < 0.001$), whereas reliability was virtually the same between the groups (83 vs. 89%, $P = 0.205$).

C-reactive protein

Diagnostic accuracy for the US group among the patients with elevated CRP-level was higher, but not among patients with normal CRP. Admission frequency or request of CT examination did not differ between the intervention groups regardless of CRP-level. The number of requested radiological US examinations or any other further examination was lower among the patients in the US group regardless of CRP-level (Table 4).

Gallbladder disease

A diagnosis of gallbladder concrement and/or cholecystitis set as the first emergency diagnosis before randomization was associated with a decreased number of further US examinations and further examinations in the US group (Table 5). In the patients presenting with symptoms of gallbladder disease (pain and tenderness in right upper abdomen), there

Table 2 Benefits of US examinations in different subgroups

	Diagnostic accuracy	Admission frequency	Requested US at radiological department	Requested CT at radiological department	Any other examination requested
BMI					
<25			X		X
≥25	X		X	X	X
CRP					
<10			X		X
≥10	X		X		X
Lower abdominal symptoms			X		
Upper abdominal symptoms	X		X		X
Gallbladder disease			X		X
Appendicitis					
NSAP		X	X		X
Peritonitis	X		X		X
Age					
<30			X		X
30–59	X		X	X	X
≥60			X		

X statistically significant benefits

Table 3 Results based on age groups

	Age < 30 (n = 177)			Age 30–59 (n = 388)			Age ≥ 60 (n = 218)		
	US (n = 87) [% (n)]	Non-US (n = 90) [% (n)]	P value	US (n = 198) [% (n)]	Non-US (n = 190) [% (n)]	P value	US (n = 107) [% (n)]	Non-US (n = 111) [% (n)]	P value
Diagnostic accuracy	65 (56)	60 (52)	0.468	68 (130)	58 (109)	0.042	58 (61)	52 (55)	0.405
Admission	38 (33)	47 (42)	0.240	40 (79)	44 (84)	0.390	52 (56)	63 (70)	0.109
Ultrasound ordered	3 (3)	27 (24)	<0.001	10 (19)	28 (53)	<0.001	11 (12)	27 (30)	0.003
CT ordered	2 (2)	2 (2)	0.973	5 (9)	12 (22)	0.011	19 (20)	14 (15)	0.297
No other examination ordered	59 (51)	38 (34)	0.006	51 (101)	29 (55)	<0.001	37 (39)	27 (30)	0.134

Partially missing data in maximum seven patients per group and analysis

was also a higher diagnostic accuracy as well as fewer requested radiological US examinations and further examinations, if examined with bedside US at the ED (Table 6).

Appendicitis

The only difference found among the patients with symptoms of appendicitis (pain and tenderness in right lower abdomen) was in the request for complementary US examinations at the radiological department with fewer requests in the intervention group (Table 6).

Peritonitis

In 100 patients, the physical examination of the patient showed signs of peritonitis. Among these patients, bedside US had an effect of higher diagnostic accuracy and fewer

requests for radiological US examinations or any other further examination. As expected, the admission frequency was high in this group of patients, and did not differ between the comparison groups (Table 6).

From the patients in this critically ill group, 23 patients in the US group and 26 in the non-US group were admitted for surgery. Of these patients requiring surgery, 14 (60.9%) in the US group and 5 (19.2%) in the non-US group were admitted for surgery with the decision taken while still at the ED (P = 0.003).

Non-specific abdominal pain

The frequency of admission was lower for NSAP patients undergoing US. The number of radiological US and further examinations was also lower in the group examined with bedside US (Table 5).

Table 4 Results based on body mass index (BMI) and C-reactive protein (CRP)

	BMI < 25 (n = 436)		BMI ≥ 25 (n = 317)		CRP < 10 (n = 403)		CRP ≥ 10 (n = 367)		P value
	US	Non-US	US	Non-US	US	Non-US	US	Non-US	
	(n = 223) [% (n)]	(n = 213) [% (n)]	(n = 160) [% (n)]	(n = 157) [% (n)]	(n = 219) [% (n)]	(n = 184) [% (n)]	(n = 163) [% (n)]	(n = 204) [% (n)]	
Diagnostic accuracy	62 (135)	58 (119)	67 (105)	54 (85)	65 (142)	62 (112)	63 (98)	52 (103)	0.047
Admission	44 (97)	48 (102)	43 (69)	52 (82)	25 (55)	34 (62)	68 (111)	65 (132)	0.495
Ultrasound ordered	7 (15)	25 (53)	11 (18)	29 (45)	7 (16)	26 (48)	11 (18)	28 (57)	<0.001
CT ordered	8 (18)	7 (15)	7 (11)	14 (22)	4 (8)	4 (8)	14 (22)	14 (29)	0.843
No other examination ordered	47 (104)	33 (70)	54 (85)	27 (42)	51 (110)	34 (62)	46 (75)	28 (57)	<0.001

Partially missing data in maximum nine patients per group and analysis

Discussion

This study is based on a large randomized clinical trial from which we have proceeded with a thorough subgroup analysis. The overall results of the randomized clinical trial have previously been presented in two earlier papers [4, 10].

Our results show that surgeon-performed US is of higher value in overweight patients (BMI 25 or more) compared to patients with lower BMI. In this specific group, we did not only have an effect on diagnostic accuracy but also a decrease in requests for radiological US examinations as well as further examinations including CT scan. This is quite surprising since a high BMI is generally considered to hamper US examinations, a fact which is supported by a previous US study showing a lower diagnostic accuracy in overweight patients (BMI > 25) for diagnosing appendicitis [19]. Our results endorse the fact that US is more difficult to perform in overweight patients, but that it is still of great value. One possible explanation is that these patients are more difficult to examine [20]. This may give the additional bedside US examination a relatively high value for diagnosing and further management purpose. The slightly larger number of examinations ordered in the overweight group may also be because the surgeon feels insecure of the clinical examination performed. One should point out that although the surgeons in our study considered the US more difficult to perform in the BMI > 25 group, they considered the performed examination reliable to the same extent in both weight groups. This is supported by the fact that more CT scans were not ordered in the overweight US groups.

The bedside US examination also gave a higher diagnostic accuracy in the group with elevated CRP. Appendicitis and cholecystitis, diagnoses that are normally connected with elevated CRP, also had high diagnostic accuracy which might be an explanation for this finding. We consider the finding important, since an elevated CRP generally indicates a more serious abdominal condition with need for immediate surgical treatment [16]. Another category of severely ill patients, with a high risk of needing immediate surgery, are those with signs of peritonitis. In this group, we likewise had a higher diagnostic accuracy with the help of US examination. Even more important though, these patients were, to a higher rate, admitted to surgery while still at the ED. This may of course reduce the risk of complications due to doctor's delay.

Regarding age groups, the lowest diagnostic accuracy at the ED for both intervention groups was seen in the oldest age group. This is in accordance with data shown in earlier reports [21]. We could though not show any increase in diagnostic accuracy in these older patients with the help of US. The only age group showing a significantly higher

Table 5 Results based on first set preliminary diagnosis at the ED

	First emergency diagnosis set as gallbladder concrement and/or cholecystitis (<i>n</i> = 61)			Appendicitis ± abscess as first emergency diagnosis (<i>n</i> = 55)			NSAP as first emergency diagnosis (<i>n</i> = 370)		
	US (<i>n</i> = 27) [% (<i>n</i>)]	Non-US <i>n</i> = 34 [% (<i>n</i>)]	<i>P</i> value	US (<i>n</i> = 31) [% (<i>n</i>)]	Non-US <i>n</i> = 24 [% (<i>n</i>)]	<i>P</i> value	US (<i>n</i> = 189) [% (<i>n</i>)]	Non-US (<i>n</i> = 181) [% (<i>n</i>)]	<i>P</i> value
Diagnostic accuracy	70 (19)	62 (21)	0.482	64 (20)	54 (13)	0.434	62 (118)	55 (99)	0.306
Admission	52 (14)	62 (21)	0.437	97 (30)	100 (24)	0.375	31 (59)	45 (81)	0.007
Ultrasound ordered	26 (7)	82 (27)	<0.001	6 (2)	21 (5)	0.112	5 (10)	30 (55)	0.001
CT ordered	0 (0)	0 (0)	–	13 (4)	8 (2)	0.590	10 (19)	10 (19)	0.902
No other examination ordered	63 (17)	18 (6)	<0.001	71 (22)	46 (11)	0.059	48 (91)	32 (57)	0.001

Partially missing data in maximum three patients per group and analysis

Table 6 Results based on symptoms and signs

	Pain and tenderness in right upper abdomen (<i>n</i> = 101)			Pain and tenderness in right lower abdomen (<i>n</i> = 187)			Peritonitis (<i>n</i> = 100) ^a		
	US <i>n</i> = 54 [% (<i>n</i>)]	Non-US (<i>n</i> = 47) [% (<i>n</i>)]	<i>P</i> value	US <i>n</i> = 91 [% (<i>n</i>)]	Non-US (<i>n</i> = 96) [% (<i>n</i>)]	<i>P</i> value	US (<i>n</i> = 51) [% (<i>n</i>)]	Non-US (<i>n</i> = 49) [% (<i>n</i>)]	<i>P</i> value
Diagnostic accuracy	72 (38)	52 (24)	0.045	59 (53)	54 (51)	0.476	74 (37)	54 (26)	0.041
Admission	50 (27)	49 (23)	0.915	62 (56)	58 (56)	0.655	90 (46)	84 (41)	0.332
Ultrasound ordered	22 (12)	74 (34)	<0.001	3 (3)	22 (21)	<0.001	10 (5)	29 (14)	0.017
CT ordered	9 (5)	6 (3)	0.615	8 (9)	9 (8)	0.911	16 (8)	24 (12)	0.271
No other examination ordered	54 (29)	17 (8)	<0.001	50 (45)	45 (43)	0.523	53 (27)	22 (11)	0.002

Partially missing data in maximum one patient per group and analysis

^a Of these patients, 23 in US group and 26 in non-US group were admitted for surgery. 14 (60.9%) in US group were admitted already at ED and 5 (19.2%) in non-US group, *P* = 0.003

diagnostic accuracy with the help of US was the middle age group between 30 and 59 years.

When grouping the patients according to symptoms suggesting appendicitis (right lower abdominal pain) and gallbladder disease (right upper abdominal pain), there was only an increase in diagnostic accuracy for the patients with right upper abdominal pain. This is in line with earlier studies showing a high diagnostic accuracy with the help of US for this group of patients [22–24]. The need for radiological examinations was lower among patients presenting with either right upper or lower abdominal pain, if examined with bedside US which shows that the study surgeon had confidence in the US performed bedside and did not require a confirmation of the US by another radiological examination.

Gallbladder disease and appendicitis are diagnoses in which it is earlier shown that US is of diagnostic value [15–17, 25]. However, we could not show any effect on diagnostic accuracy if one of these specific diagnoses was set at the ED as the first preliminary diagnosis. A reason for this

might be that US does not contribute to the same extent to the diagnosis when the clinical and laboratory tests point to a specific diagnosis. In the group with localized pain and tenderness in the right upper abdomen, the relative effect of the US examination is probably higher, which gives us a small, but significant, higher diagnostic accuracy with the US examination. The importance of the US examination is, however, best illustrated by the fact that three times as many US examinations were ordered at the radiological department in the group not examined with bedside US. This was true both if gallbladder disease was set as first diagnosis as well as if there were symptoms of the disease (Table 5). From this, we draw the conclusion that bedside US is indeed of great value in these patients, not to set the diagnosis, but to confirm it before surgery.

Acute NSAP, generally defined as acute abdominal pain of under 7 days duration and for which there is no diagnosis after examination and baseline investigations, is a common cause for admission at the ED, including about half of the patients admitted at the ED for abdominal pain

[10]. The need for admission to a hospital ward for these patients was significantly reduced in our study when the patients were examined with US at the ED.

A question that might be raised is the possible long-term side effects of the method. In an earlier study, we have nevertheless not found any differences in 2-year health care consumption or mortality between patients examined with bedside ultrasound or not at the ED when admitted for abdominal pain [26]. It is reasonable to assume that a single ultrasound examination has very little impact on mortality and long-term health condition, but a great impact on the management of the actual condition, as shown in this study.

One weakness of our study is that these examinations are subgroup analyses. The outcomes measured were primary and secondary outcomes for the study including the whole group of patients. We have now examined the same outcomes but in small sub groups. This makes the statistical power less and the detected differences yield lower evidence when the results are generalized.

The strengths of our study are that this is a randomized study including a large number of patients, and that we have achieved a nearly complete follow-up. All the more, the data were collected prospectively, and the large number of patients included makes the power in the comparisons in the subgroups acceptable.

Conclusion

This study shows that surgeon-performed US at the ED for abdominal pain can be helpful in several ways for the majority of patients admitted to the ED for abdominal pain. The benefit is even more pronounced among patients that are overweight. For patients with peritonitis, the time to surgery might be shortened, if US is performed bedside. Taking into account other shown benefits and the lack of adverse effects, we find the method well worth consideration for implementation at the ED.

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Conflict of interest None.

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