BMJ Open

Point-of-care ultrasonography in general practice affects patient care – a prospective observational study.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-037664
Article Type:	Original research
Date Submitted by the Author:	11-Feb-2020
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Keywords:	PRIMARY CARE, ULTRASONOGRAPHY, Change management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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Point-of-care ultrasonography in general practice affects patient care – a prospective observational study.

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Wordcount: 2639

Abstract

Objectives: To describe how general practitioners (GPs) use point-of-care ultrasonography (PoC-US) and how it influences the diagnostic process and treatment of patients.

Design: Prospective observational study

Setting: Office-based general practice

Participants: Twenty GPs consecutively recruited all patients examined with PoC-US in one month.

Primary and secondary outcome measures: Using an online before-after PoC-US questionnaire we explored the use of PoC-US through the frequency of PoC-US, the indication for using PoC-US, the time consumption for PoC-US, the extent of modification of the PoC-US, and the PoC-US findings.

The influence on the diagnostic process was explored through change in the tentative diagnoses, change in confidence, the ability to produce ultrasound images, and the relationship between confidence and organs scanned or tentative diagnoses.

The influence of PoC-US on patient treatment was explored through change in plan for the patient, change in patient's treatment, and the relationship between such changes and certain findings.

Results: The GPs included 574 patients in the study. PoC-US was used in 3.7% to 20.8% of their patient consultations and many different organs were scanned covering more than 100 different tentative diagnoses. The median time taken to perform PoC-US was 5 minutes [IQR: 3-8]. Across applications and GPs, PoC-US entailed a change in diagnoses in 49.4% of patients; increased confidence in a diagnosis in 89.2% of patients; a change in the management plan for 50.9% of patients; and a change in treatment for 26.5% of patients.

Conclusions: PoC-US in general practice is used for a large number of different clinical conditions. Among the GPs who used PoC-US in their clinical work, some used it rarely, others in one-in-five consultations. Overall, using PoC-US changed the GPs' diagnostic process and clinical decision-making in nearly three out of four consultations.

Trial registration: Clinical trials registration number: NCT03375333

Strengths and limitations of this study

This study is the first to report the use of point-of-care ultrasound in a broader sample of general practitioners, who have implemented the technology without formal prerequisites or supporting guidelines.

Despite using a broader sample of general practitioners, the participants most likely constitute a selected group of physicians with a special interest in ultrasonography.

The study was developed through a comprehensive qualitative work, designed to mimic daily practice and to avoid recall-bias or post-rationalization in the registrations.

The study registrations were time-consuming and the participating general practitioners included fewer patients than expected.

Point-of-care ultrasound changed diagnosis, plan or treatment for the majority of patients, but we did not evaluate whether these changes improved or worsened patient care.

Introduction

Point-of-care ultrasound (PoC-US) is used in general practice in several countries.[1-4] A recent systematic review found that few studies described the use of PoC-US in the hands of the general practitioner (GP) and that obstetric, abdominal, and heart examinations were the most commonly described.[5] The included studies, however, focused on selected scanning modalities and largely aimed to explore a possible transition of ultrasound examinations from secondary to primary care. The recent introduction of PoC-US, as something disparate from ultrasound examinations performed by radiologists or other highly specialised physicians[6,7], prepares the ground for more widespread use, as it encourages clinicians to apply PoC-US as part of the physical examination of patients.[8,9] Hence, the current use of PoC-US in general practice may differ from use previously reported. No previous studies have quantified the use of PoC-US in a larger group of GPs with different types of ultrasound training, who have adopted the technology without either constraining or supporting guidelines and without financial incentives.

Evidence from the secondary healthcare sector has shown that certain PoC-US applications affect the diagnostic process leading to earlier and more correct diagnosis,[10,11] a subsequent change in patient treatment, and a more rational use of healthcare resources.[12,13] A few recent studies from general practice suggest the same.[14-16] Little attention has been given, however, to the specific impact of PoC-US on the diagnostic process in general practice and GPs' clinical decision making.

The aim of this study was to describe how GPs use PoC-US in their daily practice and how it influences the diagnostic process and the treatment of patients.

Method

Study design

This prospective observational study was registered in clinical trials (registration number: NCT03375333) prior to recruiting participants. We report the study findings according to STROBE guidelines.

Study setting

The study was conducted in office-based general practices in Denmark, where GPs were already using PoC-US. Denmark has a public healthcare system, where almost all patients are registered with a GP for tax-financed primary healthcare services that are free at the point of need. The GPs act as gatekeepers for secondary care services including ultrasonography. GPs receive no fee for performing PoC-US in primary care.

Participating general practitioners

Twenty GPs were recruited through PoC-US networks, conferences, and teaching sessions (Appendix 1). To be included in the study, GPs had to have used PoC-US for a minimum of six months; had to apply PoC-US to a minimum of two anatomical areas; had to use PoC-US on a daily basis, and had to have some level of formalised PoC-US training. Participating practices needed a minimum of 1400 patients on their lists and the GPs had to work in their practice a minimum of four days a week. GPs with an ultrasound system more than 10 years old or with any possible financial conflict of interest were excluded. The GPs were enrolled in the study stepwise from January 2018 to August 2018 to account for any seasonal variation in PoC-US examinations. Prior to the study, participating GPs' PoC-US competences were assessed using a modified version of the Objective Structured Assessment of Ultrasound Skills (OSAUS)[17] and an objective structured clinical examination (OSCE) evaluation sheet (Appendix 2). The GPs were blinded to the results of this assessment.

Participating patients

All patients who sought care for conditions that the participating GP found relevant for PoC-US examination were invited to participate in the study.

Data collection and study procedure

The GPs consecutively registered information on all PoC-US examinations during one month (20 to 25 working days), while performing PoC-US according to their usual indications and standards and using their own ultrasound systems. When a GP planned to use PoC-US, the patient received study information and a written informed consent was obtained. Thereafter the GPs accessed an online SurveyXact questionnaire (Rambøll, Aarhus, Denmark) and completed items before and after conducting PoC-US. A time log measured the time between the before and the after PoC-US registrations. (See Appendix 3 for questionnaire details).

We also registered the total number of face-to-face patient consultations during the study period and the number of eligible patients who were not included due to e.g. time constraints. The primary investigator (CAA) visited the GPs' clinics on the first day of inclusion to help with the registrations and to perform a validity test of the GPs' registration.

Outcome measures

The use of PoC-US in general practice was explored through: (1) the indication for using PoC-US; (2) the frequency of PoC-US; (3) the time consumption for PoC-US; (4) the extent of modification of the PoC-US; and (5) the PoC-US findings.

The influence of PoC-US on the diagnostic process in general practice was explored through: (1) change in the tentative diagnoses according to the international classification of primary care 2nd edition (ICPC2)[18] before and after PoC-US; (2) The GP's declared change in confidence in the main tentative diagnosis after the use of PoC-US; (3) The GP's ability to technically produce ultrasound images; (4) the relationship between confidence in the main tentative diagnosis and organs scanned, reduction in the number of tentative diagnoses, and change from symptom to disease-specific diagnoses.

The influence of PoC-US on patient treatment in general practice was explored through: (1) change in plan for the patient; (2) change in patient's treatment; (3) the relationship between certain findings and changes in the plan for treatment or treatment of the patient.

Sample size and statistical analysis

Assuming that GPs used PoC-US 2-3 times daily we expected to include between 640 and 960 patients.[16] Data was analysed using STATA V.15.0 (StataCorp, College Station, Texas, USA) according to a predefined analysis plan (Clinical trials registration number: NCT03375333). Categorical variables were summarised using absolute frequencies and continuous variables using mean and standard deviation (median and interquartile range if not normally distributed). Our predefined hypotheses, all published in clinical trials, about the relationship between variables were analysed using Fishers exact test and a significance level of 0.05

Ethical approval

Written informed consent was obtained from all participating GPs and patients and all data was pseudo-anonymised. The study was approved by the Danish Data Protection Agency and the Committee of Multipractice Studies. The study was also notified to the Regional Committee on Health Research Ethics, but they responded that their approval was not needed according to Danish law.

Patient and public involvement statement

Patients were involved and invited to provide feedback during the design and pilot testing of the registration tools used in this study.

Results

Twenty general practitioners from 18 clinics included between 9 and 75 patients. Data from 574 patients were available for analysis, and in 528 patients data were available for before-after comparison (Figure 1). Background characteristics are given in Table 1.

PoC-US competences were assessed in 19 GPs covering between two and six applications, depending on their normal use of PoC-US (Figure 2 and Appendix 2).

The use of PoC-US

The GPs performed between 12 and 84 PoC-US examinations corresponding to an average of between 0.6 and 3.9 ultrasound examinations per day. The GPs had between 13.0 and 24.4 face-to-face patient consultations per day. Hence, during the study period PoC-US was performed in between 3.7% and 20.8% of all face-to-face consultations.

When GPs were using PoC-US they aimed primarily to answer a clinical question (73.1%), and also to explore the reason for the patient's symptoms (20.2%), but they rarely planned to do both (1.6%). A total of 126 different ICPC2 codes were registered as the primary tentative diagnosis before the use of PoC-US (Appendix 4).

PoC-US was used to examine many different organs (Figure 3). The GPs registered scanning 834 different organs in 570 PoC-US examinations; most commonly heart and lung in combination and different combinations of abdominal organs. In addition, we found that GPs modified their PoC-US examination to include more organs than intended in 15.5%, and fewer organs than intended in 8.0% of all ultrasound examinations.

The median time consumption for the PoC-US examination was 5 minutes [IQR: 3-8] but varied from 1 to 30 minutes (Figure 3).

Images of the relevant structures could be produced in between 95% and 100% of the applications, though some seemed to cause more difficulty: lymph nodes (75%); pancreas (75%); ovaries (78%); heart (89%); kidney (93%), and others (86%).

The GPs classified their PoC-US examinations to include: certain positive findings (45.7%); uncertain positive findings (9.3%); certain negative findings (32.3%); uncertain negative findings (10.2%), and different combinations of these findings (1.7%). In addition, the GPs registered incidental findings in six patients.

PoC-US influence on the diagnostic process

PoC-US changed the main tentative diagnosis in 49.4% of consultations (Figure 4 and Appendix 4). This encompassed a reduction in the number of patients where the GP had more than one tentative diagnosis from 29.6% before to 17.5% after the PoC-US examination. There was also a reduction in the number of symptom diagnoses and a corresponding increase in the number of disease-specific, infection-related, cancer-related and emergency-related diagnoses after as compared to before the PoC-US examination (Appendix 5).

After PoC-US, the GPs declared the following change in their confidence in the primary tentative diagnosis: highly increased confidence (60.5%); increased confidence (28.5%); unchanged confidence (6.6%); reduced confidence (1.0%), and highly reduced confidence (0.1%). Seven consultations entailed reduced confidence, the applications in these examinations were: heart (1), lung (1), thyroid and lymph nodes (1), subcutaneous process (1), gallbladder, liver and pancreas (1), tendon (1) and uterus (1). Increased confidence did not seem to depend on area of PoC-US application as we found no variation beyond what could be expected by chance (0.082). Likewise, no relationship was found between a reduction in the number of tentative diagnosis and increased confidence (P = 0.127). We did, however, find a relationship between increased confidence and a change from symptom diagnosis to disease-specific diagnosis (P = 0.037).

PoC-US influence on patient treatment

PoC-US changed the intended plan for patients in 50.9% of consultations (Figure 4), including a reduction in the absolute number of patients referred to hospital or secondary care clinics from 174 (33.0%) to 105 (19.9%) patients, and a reduction in the number of patients referred for imaging in the secondary sector from 86 (16.3%) to 30 (5.7%). Correspondingly, the number of patients with planned follow-up in primary care increased from 185 (35.0%) to 215 (40.7%), and patients with no planned follow-up increased from 106 (20.1%) to 198 (37.5%) following PoC-US (Appendix 6).

After PoC-US, the intended treatment was changed in 26.5% of consultations (Figure 4). The number of patients planned for referral to treatment in the secondary sector fell from 87 (16.4%) to 63 (11.9%). The number of patients where the GP would not initiate treatment fell from 283 (53.6%) to 269 (50.9%); whereas the number of patients where the GP initiated treatment increased from 168 (31.8%) to 208 (39.4%) (Appendix 6). We found no relationship between the GPs' classification of certain findings and a change in the patient's plan (p=0.913), or change in the patient's treatment (p=0.214).

Overall change as a result of PoC-US (change in diagnosis and/or change in the patient's plan and/or change in the patient's treatment) was found in 71.8 % of consultations.

Discussion

Summary of main findings

This study showed that across applications PoC-US had a large impact on the diagnostic process in general practice. PoC-US changed the tentative diagnoses in 49.4% of patients and increased confidence in the main tentative diagnosis in 89.2% of patients. PoC-US changed the planned management plan in 50.9% of patients, including an absolute reduction in intended referrals from 49.2% to 25.6%, and a change in the planned treatment of 26.5% of patients.

Strengths and limitations

This study had a broader sample of scanning GPs than most reported studies. Furthermore, the registration tool was developed through comprehensive qualitative work and pilot testing. We designed the study to mimic daily work and to avoid recall-bias in the registrations. Furthermore, the GPs were blinded to the results of their competence evaluations.

We included fewer patients than expected. The patient information and study registrations added 10 minutes to the consultation and, due to time constraints, GPs may have chosen not to perform some PoC-US examinations. Hence the frequency of PoC-US reported in this study may be underestimated.

The participating GPs varied considerably in their background characteristics, but given their interest in PoC-US, they most likely constitute a select group compared to a broader population of GPs.

We used Fishers exact test to explore overall associations. Due to the lack of statistical power, however, no firm conclusions can be made regarding the relationship between the GP's confidence in the main tentative diagnosis and the organs scanned.

Findings in context

In line with previous research,[2,5,19] we found large variation in the application of PoC-US in general practice. The most common applications in this study were pelvic and musculoskeletal PoC-US. This may be explained by the fact that all participating GPs had received training in pelvic PoC-US and all but two had participated in a musculoskeletal PoC-US course. Another explanation may relate to patient encounters in Danish general practice. A previous qualitative study has described how Danish GPs perform PoC-US examinations that they consider relevant in their patient population[16] and musculoskeletal conditions are the most common organ-specific complaints raised by patients in Danish general practice.[20] Moreover, in a recent needs-assessment, pelvic ultrasound was found to be the PoC-US application GPs had most interest in learning.[21]

This study illustrates that PoC-US is used to support the physical examinations of patients presenting with a very broad range of clinical conditions. There have been attempts to outline which PoC-US examinations are best suited to general practice.[4,19,21-24] The evidence base for these attempts is sparse, however, and there may be significant differences between countries regarding which examinations are most relevant.[3] In addition, some examinations may be easier to master than others,[5] both in terms of achieving competence and in terms of maintaining competence over time. The latter may be particularly important in general practice where the frequency of some PoC-US examinations is as low as shown in this study (Figure 3). Some of the GPs had a low OSAUS competence score, despite having participated in training (Figure 2). Likewise, we found that some PoC-US examinations resulted in reduced confidence in the diagnosis and GPs described findings as uncertain in 19.7% of patients. Office-based GPs may be used to navigating in uncertainty and performing up to a certain level before referring patients on to more advanced care. Still, PoC-US is a particularly user-dependent technology[22,25] and the ability to rule-in or rule-out, as well as the prevalence and interpretation of incidental findings, may differ between applications.[5,26.] Thus, there is a need for evidence-based guidelines to support GPs in choosing what to scan.

Previous studies from hospitals have shown that some PoC-US examinations entail a change in patient care[10,11,27-29] and our study suggests that this finding also applies in primary care. The GPs' registration data showed that 49.2% of patients would have had onward referral if PoC-US had not been available. This referral frequency was reduced to 25.9% by using PoC-US, whereas the number of patients with planned follow-up in general practice, or no follow-up, increased. Previous studies from general practice have suggested a reduction in referrals,[14,30] but how PoC-US in general practice affects overall healthcare costs is unknown.

Implications for practice

The GPs used PoC-US in 3.7% to 20.8% of their consultations with a median time consumption of five minutes. Hence, the use of PoC-US is feasible in general practice despite differences in ultrasound equipment, experience, educational background, and choice of examinations. PoC-US largely impacted diagnostic certainty and patient management. It remains to be investigated, if the change in patient

management caused by PoC-US actually improves patient care, or if it causes harm in terms of false positive findings, misdiagnosis, over-detection, and potential, subsequent overtreatment.

Conclusion

PoC-US examinations in general practice were used for many different indications and entailed an increased diagnostic reassurance for the GP and a change in diagnosis or management in 71.8% of patients. The potential high impact of PoC-US underlines the need for further research to support an appropriate implementation of PoC-US in general practice.

List of abbreviations

PoC-US = Point-of-Care Ultrasonography

GP = General practitioner

OSAUS = Objective Structured Assessment of Ultrasound Skills

OSCE= Objective structured clinical examination

ICPC2= The international classification of primary care 2nd edition

Acknowledgements

The authors would like to thank the participating GPs for their individual contributions and the Danish Society for Ultrasound in General Practice (DAUS) for non-financial support of the study.

Conflict of interest statement

The authors report no conflicts of interest.

Funding statement

This study was conducted as independent research financially supported by the Committee of Multipractice Studies in General Practice and The Danish Research Foundation for General Practice.

Author contributions

CAA, JB, ASD, OG and MBJ all participated in designing the study and developing the registration tools. CAA recruited and instructed the participating GPs prior to the study. OG performed the evaluation of the participating GPs PoC-US competences. Data collection and analysis was performed by CAA and MBJ. CAA wrote the first draft of the article in collaboration with MBJ. All authors participated in the following review process and contributed to the final version of the article.

Data availability statement

All study data are safely stored at Center for General practice at Aalborg University in Denmark and available upon reasonable request to the corresponding author.

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Table 1. Background characteristics

Characteristics of the clinics N=18		Characteristics of the GPs N=20		Characteristics of the patients N=574*	
Location in Denmark		**Age**		**Age**	
North Denmark Region	4(22.2)	< 40 years	2(10.0)	< 30 years	98(17.1)
Central Denmark Region	3(16.7)	40-50 years	14(70.0)	30-50 years	198(34.5)
Region of Southern Denmark	5(27.8)	51-60 years	3(15.0)	51-70 years	188(32.8)
Region Zealand	2(11.1)	> 60 years	1(5.0)	> 70 years	90(15.7)
Capital Region of Denmark	4(22.2)	Mean: 46.2 (95%CI: 43.2-49.1) years		Mean: 49.7 (95%CI: 48.2-51.1) years	
Location classified by the GP		**Gender**		**Gender**	
Urban	10(55.6)	Male	14(70.0)	Male	191 (33.3)
Mixed	6(33.3)	Female	6(30.0)	Female	383 (66.7)
Rural	2(11.1)				
Practice size		**Experience as a general practitioner**			
< 2000 patients	3(16.7)	< 10 years	12(60.0)		
2000-5000 patients	9(50.0)	10–20 years	7(35.0)		
> 5000 patients	6(33.3)	> 20 years	1(5.0)		
Type of practice		**Experience using ultrasonography**			
Partnership practice	15(83.3)	< 2 years	6(30.0)	* For comparison, excluded patients (N= 117) were 29.1% male and with a mean age of 43.2 (95%CI: 38.9-47.5) years.	
Solo-practice	1(5.5)	2-5 years	11(55.0)		
Collaboration practice	2(11.1)	> 5 years	3(15.0)		

Number (percentage) of the total number of participants in each group (N)

Figure 1.

[Attached in a separate file]
Figure legend: Patient flow diagram

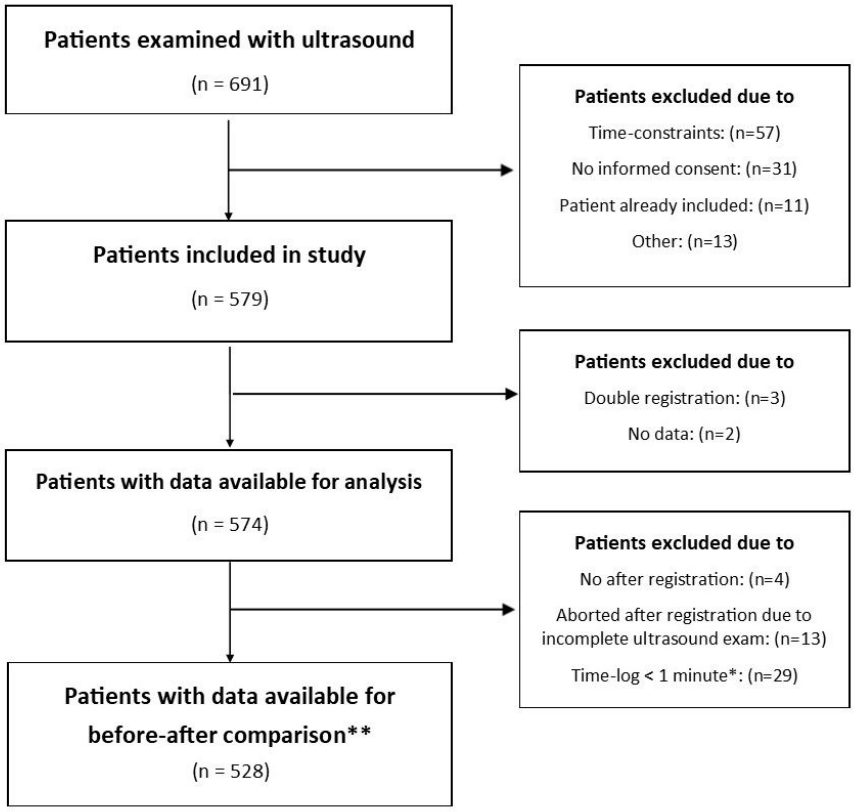
Figure 2.
[Attached in a separate file]
Figure legend: Ultrasound competences of the participating general practitioners

Figure 3.
[Attached in a separate file]

Figure legend: Use of ultrasonography in general practice

Figure 4.
[Attached in a separate file]
Figure legend: Change in patient care after the use of ultrasonography

Figure 1 Patient flow diagram



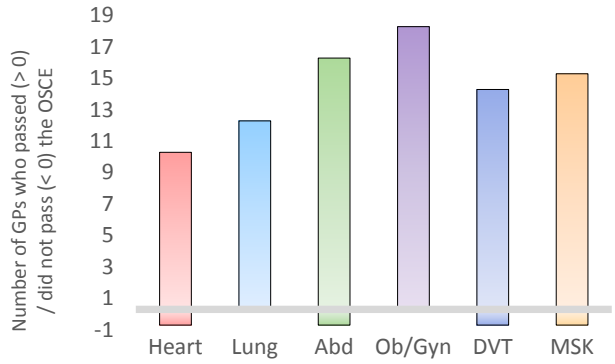
* Time-log < 1 minute = No separation between before and after registration in the questionnaire. Before-registration was deleted.

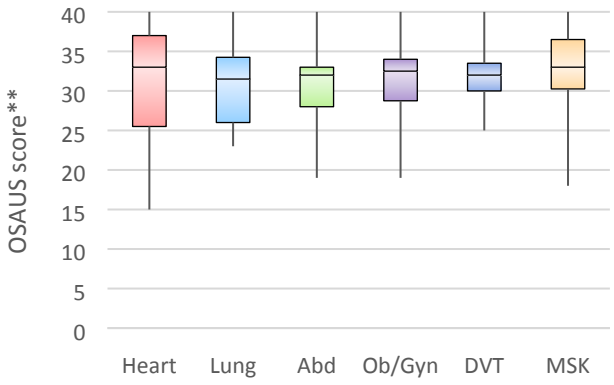
** We had 545 before registrations, 557 after registrations and 528 complete before and after registrations.

Figure 2 Ultrasound competences of the participating general practitioners.

Assessment of ultrasound competences (N=19)*

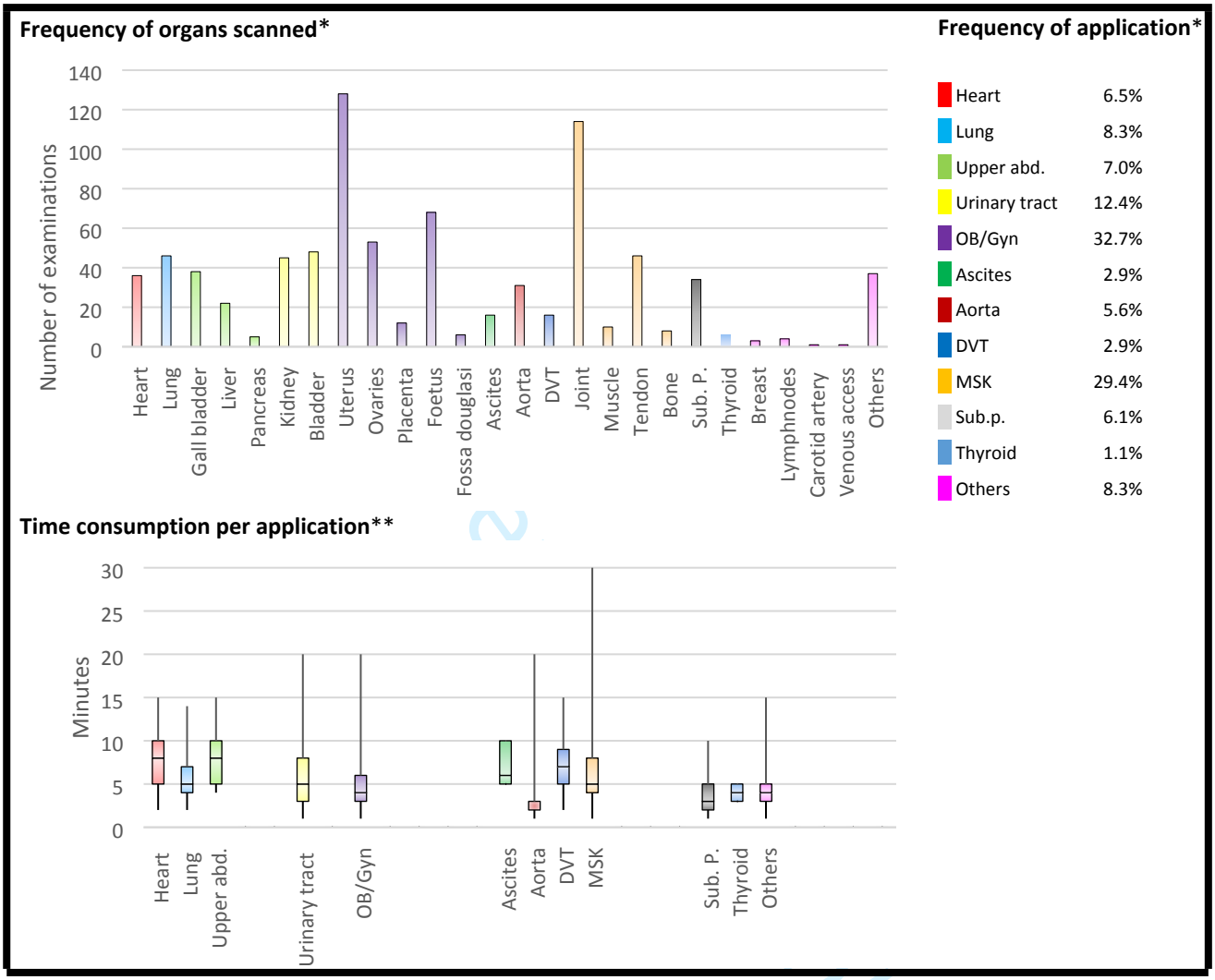
OSCE evaluation	OSAUS evaluation
Sixteen GPs (84.2%) passed the OSCE evaluations for all applications. One GP failed to pass two out of six applications: Heart (incorrect probe placement) and abdomen (wrong measurement of bladder volume) One GP failed to pass one out of four applications: DVT (unsystematic approach and incorrect placement of probe) One GP failed to pass one out of two applications: MSK (insufficient knowledge, unsystematic approach and incorrect probe placement).	The average individual OSAUS scores** varied from 18.5 to 40.0 across applications while the OSAUS scores for each application across GPs varies from 15.0 to 40.0.





* A teacher in PoC-US and radiology specialist (OG) assessed 19 of the GPs' performances in a standardised setting using an adapted version of a generic ultrasound rating scale (The Objective Structured Assessment of Ultrasound Skills (OSAUS)[17]) and asked questions about the examination according to an objective structured clinical examination (OSCE) evaluation sheet. The GPs were asked to demonstrate PoC-US according to their usual routine and they were only assessed in the applications that they normally used.
One GPs declined to participate in this evaluation.
** OSAUS: objective structured assessment of ultrasounds skills assessed on a scale from 0-40.
GP= general practitioner, Abd= abdomen, Ob/Gyn= Obstetric and gynaecological, DVT= Deep venous thrombosis, MSK= musculoskeletal

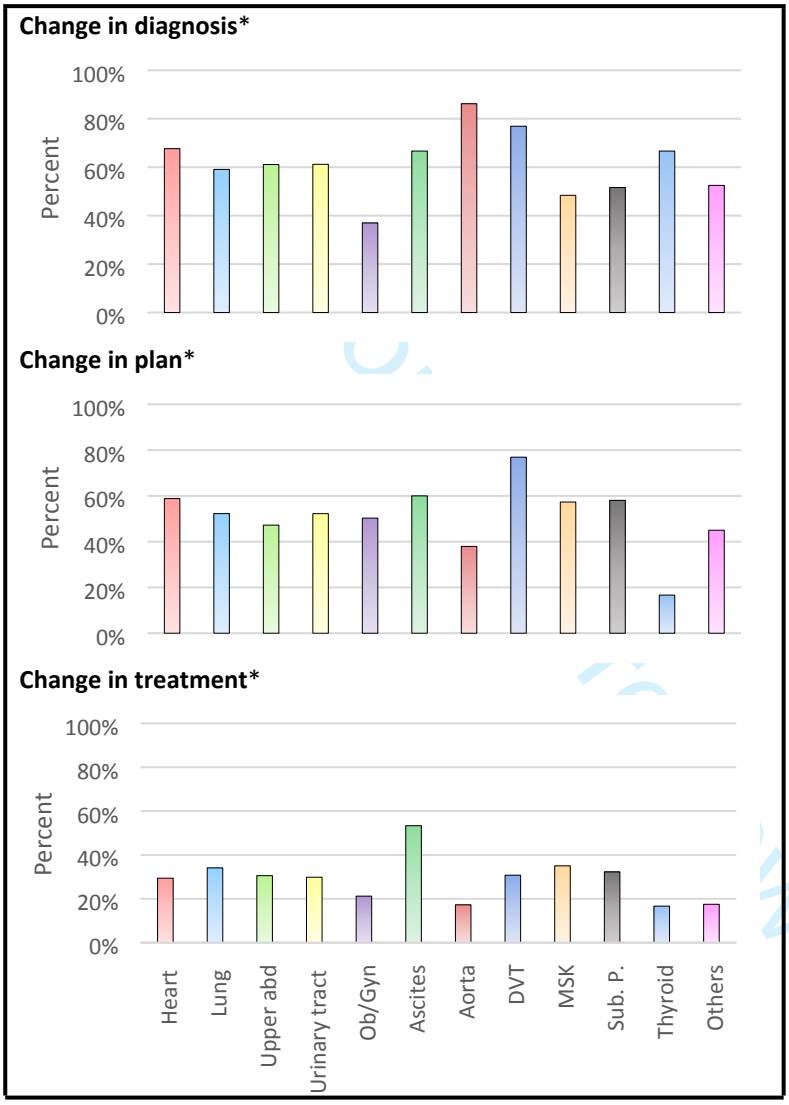
Figure 3 Use of ultrasonography in general practice



* After registrations of organs scanned (N= 557) Categorised by application the number of examinations were: *OB/Gyn*= Obstetric and gynaecological: 182 (including uterus, ovaries, placenta, foetus, and fossa douglasi); *MSK*= musculoskeletal: 164 (including joints, muscle, tendon, bone, and joint puncture); *Urinary tract*: 69 (including kidney, and bladder); *Lung*: 46; *Upper abd*= Upper abdominal organs: 39 (including liver, gall bladder, pancreas); *Heart*: 36; *Aorta*: 31; *Sub.P*= Subcutaneous process: 34; *DVT*= Scans for deep venous thrombosis: 16; *Ascites*= scans for abdominal flee fluid: 16 and *Thyroid*: 6 and *Others*: 46. The *others* category includes free text answers and registered applications with a frequency below five examinations: intestines incl. appendix and rectum (N=7), bursa (N=6), unclassified abdominal structures (N=6), testis (N=5), amnion fluid (N=4), lymph nodes (N=4), breast (N=3), soft tissue (N=2), hernia (N=2), ureter (N=1), Larynx (N=1), varicose vein (N=1), unclassified abscess (N=1), carotid artery (N=1), blood vein for venous access (N=1) and unclassified structure on finger (N=1).

** Time registration if examination only included one application (N=486). Described as median time consumption, interquartile range and range

Figure 4. Change in patient care after the use of ultrasonography



* Before-after registrations (N=528)

Upper abd= Upper abdominal organs, OB/Gyn= Obstetric and gynaecological, DVT= Deep venous thrombosis, MSK= musculoskeletal, Sub.P= Subcutaneous process

Appendix 1: Recruitment of participating general practitioners

General practitioners (GPs) were recruited through ultrasound networks, conferences, and teaching sessions. Interested GPs were asked to answer a questionnaire including background information. We included the first 20 GPs, who based on the questionnaire, met the inclusion and exclusion criteria.

Between January 2018 and August 2018, 20 general practitioners from 18 general practice clinics were included through the Danish society of ultrasound in general practice (N=10), an ultrasound group on Facebook (N=8), and teaching sessions (N=2).

Questionnaire including background characteristics

Question number	Question	Catagory
BQ 1.1	How old are you?	Age
BQ 1.2	Are you a woman/man?	Gender
BQ 1.3	How many years have you been a GP?	Experience
BQ 1.4	Which year did you graduate as a doctor?	Experience
BQ 1.5	How long have you been using ultrasound?	Experience
BQ 1.6	Would you characterize your practice as a predominantly rural, urban or mixed	Location
BQ 1.7	How is your practice organized? (solo, partnership, collaboration)	Organization
BQ 1.8	How many patients are assigned to your practice?	Organization
BQ 1.9	How many days a week do you do clinical work?	Organization
BQ 2.0	In which region do you practice?	Location
BQ 2.1	What is the approximate distance from your practice to the nearest radiology department where US can be performed?	Location
BQ 2.2	What kind of US device (name, model, year) and probes do you have?	Equipment
BQ 2.3	What kind of ultrasound education/training did you receive?	Experience
BQ 2.4	Which anatomical areas do you scan with ultrasound?	use
BQ 2.5	How often do you use ultrasound?	Frequency
BQ 2.6	Do you have a conflict of interest, participating in this study?	COI

Appendix 2: Evaluation of ultrasound competences

Each participating GP was invited to a one-hour individual meeting 1-16 days prior to the beginning of the data collection. In this meeting, the participating GP was introduced to the data collection tools and the study procedure by the principal investigator. Additionally, each GP participated in individual session where their ultrasound competences were evaluated by a radiologist.

Evaluation procedure

In the evaluation session, GPs were asked to perform ultrasound examinations, as they would normally perform them in their own clinic. GPs were provided with the opportunity to use their own ultrasound device or one of four midrange ultrasound devices: (1) The ACUSON P500 Ultrasound System from Siemens Healthcare (Erlangen, Germany), (2) The Flex Focus 400 from BK Medical Holding Company (Herlev, Denmark), (3) The M-Turbo® ultrasound system from FUJIFILM SonoSite (Bothell, USA) or (4) The LOGIQ P9 from GE Healthcare (Chicago, USA). Ultrasound examinations were performed on healthy volunteers (medical students or a soldier) and a gynecological phantom.

For this study, we used assessment tool developed and used in the certification of general practitioners following an ultrasound course[1]. These assessment tool included evaluation of ultrasound competences within the following applications: Heart (FATE protocol[2]), lung (LUS protocol[3]), Abdominal (including FAST protocol[4] and focused assessment of the gallbladder (Cholecystitis, gallstones), kidneys (hydronefrosis), bladder(residual urine) and aorta(abdominal aortic aneurism)), deep venous thrombosis (2-point-compression protocol[5]), musculoskeletal (focused assessment of joints, tendons and muscles) and gynaecological (location of intrauterine device, Location of intrauterine foetus, detection of foetal heartbeat, head position in third trimester, detection of fluid in fossa douglasi). The participating GPs used a range of different ultrasound applications during their daily clinical work. Some more than others. GPs were only asked to demonstrate ultrasound examinations within applications that they used during their daily clinical work.

The evaluation sessions included assessment of one ultrasound application after another. The participating GPs demonstrated their ultrasound competences by scanning healthy volunteers (and/or a transvaginal ultrasound training phantom) while a radiologist assessed their skills and asked questions about the examination. After each demonstration, the participants were presented with two application-specific clinical cases from general practice including ultrasound videos with pathology. The participants were then asked to interpret the videos and integrate the findings into the context of the case.

Assessment tools

After this scanning sessions the radiologist evaluated the participants' ultrasound competences for each application using a modified version of the generic ultrasound rating scale *The Objective Structured Assessment of Ultrasound Skills* (OSAUS)[6] and an *objective structured clinical examination* (OSCE)[7].

The generic OSAUS evaluation included assessment (rated on a scale: 1-5 points) of the participants': (1) knowledge of the indication for the examination, (2) applied knowledge of ultrasound equipment, (3) performed image optimization), (4) systematic approach while performing the examination, (5) ability to Interpret images, (6) documentation of the examination, and (7) medical decision making. The generic OSAUS score was adapted to a general practice setting by removing assessment of participant's ability

to document ultrasound images, as the GPs were unable to document ultrasound images in their medical record system. Additionally, the generic scale was extended with two clinical cases from general practice to further assess the clinical decision making (rated on a scale: 1-5 points). Hence, the adapted OSAUS score included a scale from 0-40 points.

The OSCE evaluation was designed to evaluate the participants' clinical skill performance. The radiologist gave the participants marks on a mark scheme for each step that they perform correctly. Based on the marks, the radiologist made an overall evaluation of each participant for each applications (passed/not passed).

The evaluation of the participants' ultrasound competences resulted in an individual OSAUS score (0-40 points) and an individual passed/not passed OSCE result for each application. The participating GPs were blinded to the results of this evaluation.

OSAUS evaluation

Application: _____

Indication for the examinations	**1**	**2**	**3**	**4**	**5**
If applicable. Reviewing patient history and knowing why the examination is indicated.	Displays poor knowledge of the indication for the examination		Displays some knowledge of the indication for the examinations		Displays ample knowledge for the examination
Applied knowledge of ultrasound equipment	**1**	**2**	**3**	**4**	**5**
Familiarity with the equipment and its functions i.e. selecting probe, using buttons and application of gel	Unable to operate equipment		Operates the equipment with some experience		Familiar with operating the equipment
Image optimization	**1**	**2**	**3**	**4**	**5**
Consistently ensuring optimal image quality by adjusting gain, depth, focus, frequency etc.	Fails to optimize images		Competent image optimization but not done consistently		Consistent optimization of images
Systematic examination	**1**	**2**	**3**	**4**	**5**
Consistently displaying systematic approach to the examination and presentation of relevant structures according to guidelines	Unsystematic approach		Displays some systematic approach		Consistently displays systematic approach
Interpretation of images	**1**	**2**	**3**	**4**	**5**
Recognition of image patterns and interpretation of findings	Unable to interpret any findings		Does not consistently interpret findings correctly		Consistently interpret findings correctly
Medical decision making	**1**	**2**	**3**	**4**	**5**
Ability to integrate scan results into the care of the patient and medical decision making	Unable to integrate findings into medical decision making		Able to integrate findings into a clinical context		Consistently integrates findings into medical decision making
Case 1	**1**	**2**	**3**	**4**	**5**
Case 2	**1**	**2**	**3**	**4**	**5**

OSCE evaluation of focused ultrasound assessment of the heart (FATE protocol)

	yes
Is able to account for indication and possible contraindications for performing the examination	

Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for Subcostal four chamber image	
Correct placement of transducer for Subcostal inferior vena cava image	
Correct placement of transducer for Apical four chamber image	
Correct placement of transducer for Parasternal long axis image	
Correct placement of transducer for Parasternal short axis image	
Correct placement of transducer for pleura image	
Is able to account for findings in relation to pericardial effusion	
Is able to account for findings in relation to cardiomyopathy	
Is able to account for findings in relation to reduced ejection fraction	
Is able to account for findings in relation to right ventricular stress	
Is able to account for findings in relation to the size of inferior vena cava.	
Is able to demonstrate a systematic approach in the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound assessment of the lung (FLUS-protocol)

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for anterior positions with the patient in the sitting position	
Correct placement of transducer for posterior positions with the patient in the sitting position	
Correct placement of transducer for anterior and lateral positions with the patient laying down	
Correct placement of transducer for posterior positions with the patient laying down	
Is able to account for findings in relation to the diagnosis and exclusion of pneumothorax	
Is able to account for findings in relation to the diagnosis and exclusion of interstitial syndrome	
Is able to account for findings in relation to the diagnosis and exclusion of pleura effusion	
Is able to account for ultrasound findings in patients with Chronic Obstructive Pulmonary Disease (COPD)	
Is familiar with procedure-related lung ultrasound	
Is able to demonstrate a systematic approach in the examination	
Is able to account for the impact of the patient position on the interpretation of the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to give examples of dynamic changes in relation to pathological findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound assessment for deep vein thrombosis

(2-point compression protocol)

	Yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Correct position of patient	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for scanning proximal veins	
Correct placement of transducer for scanning veins in fossa poplitea	
Is able to account for findings that are diagnostic for deep vein thrombosis	
Is able to account for findings that rule-out deep vein thrombosis	
Is able to demonstrate a systematic approach in the examination	
Is able to account for typical locations of a thrombus in relation to deep vein thrombosis	
Is able to account for the importance of the patients position when interpreting images	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound of the abdomen

(FAST protocol and focused assessment of Gallbladder, kidneys, aorta, bladder)

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for assessing aorta (detection of abdominal aortic aneurism)	
Correct measure of the abdominal aortic diameter	
Correct placement of transducer for assessning the gall bladder (gallstones and Cholecystitis)	
Correct demonstration of Murphys sign	
Correct measurement of gallbladder wall	
Correct placement of transducer for scanning kidneys and assessing hydronefrosis	
Is able to account for typical locations of hydronefrosis	
Correct placement of transducer for scanning bladder and assessing recidual urine	
Correct measure and calculation of bladder volume	
Correct placement of transducer for detection abdominal free fluid (ascites)	
Is able to account for free fluid in fossa hepatorenale, fossa splenorenale and fossa Douglasi / rectovesciale	

Is able to explain the effect of fasting for the outcome of the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathology on FAS-USS	
This ultrasound competence is approved	

OSCE evaluation of focused pelvic ultrasound

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer (both endovaginal and abdominal transducer)	
Correct placement of transducer for assessing uterus and ovaries	
Correct selection of transducer and correct placement of transducer for location IUD	
Correct selection of transducer and correct placement of transducer for detecting an intrauterine pregnancy	
Correct selection of transducer and correct placement of transducer for detecting an extra uterine pregnancy	
Correct selection of transducer and correct placement of transducer for detecting a fetal heart beat	
Correct selection of transducer and correct placement of transducer for estimation of gestational age (CRL)	
Correct selection of transducer and correct placement of transducer for detecting abdominal free fluid	
Is able to account for free fluid in fossa hepatorenale, fossa splenorenale and fossa Douglasi / rectovesciale	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathological finding on pelvic ultrasound	
This ultrasound competence is approved	

OSCE evaluation of focused musculoskeletal ultrasound

	JA
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for assessing effusion surrounding the long head of the biceps muscle (caput longum biceps bracii)	
Correct placement of transducer for assessing tenosynovitis in the long head of the biceps muscle (caput longum biceps bracii)	
Correct placement of transducer for detection of inflammation in the bursa (bursitis subacromialis)	
Correct placement of transducer for detection of lateral epicondylitis (tennis elbow)	
Correct placement of transducer for assessing fluid accumulation in the knee (The suprapatellar bursa)	
Correct placement of transducer for detection of Patella Tendinopathy (Jumpers knee)	
Correct placement of transducer for assessing ligamentum patellae	
Correct placement of transducer for detection of Osgood-Schlatter	
Correct placement of transducer for detection of Achilles tendinitis	

Correct placement of transducer for detection of Achilles peritendinitis	
Correct placement of transducer for detection of rupture in the Achilles tendon	
Correct placement of transducer for detection of fascia plantaris tendinitis	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathological finding on musculoskeletal ultrasound	
This ultrasound competence is approved	

(1) Center for clinical ultrasound (CECLUS) at Aarhus University, Denmark. Ultrasound course for general practice. Available at: https://health.au.dk/uddannelse/efter-og-videreuddannelse/kurser/ultralyd/ultralyd-i-almen-praksis-ceclus/. Accessed on 27-10-2019

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(3) Laursen CB, Knudsen L, Sloth E. Lun-geultralydskanning (LUS). I: Bitsch M, Jensen F red. Klinisk ultralydskanning. København: FADL's Forlag; 2011. s.167 – 179.

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(5) Adhikari S, Zeger W, Thom C, Fields JM. Isolated deep venous thrombosis: implications for 2-point compression ultrasonography of the lower extremity.Ann Emerg Med. 2015; 66:262–266. doi: 10.1016/j.annemergmed.2014.10.032.

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Appendix 3: Before-After Questionnaire

Developing the before-after questionnaire:

The registration tools included a before-after PoC-US questionnaire developed on the basis of an interview study conducted in Danish general practice(16). The questionnaire was pilot tested in consecutive rounds of one-week registrations - first by the authors (CAA and MBJ) and secondly by five GPs. Adaptions followed after each round according to feedback from both GPs and patients.

The before-after questionnaire was developed to avoid missing values. However, missing data occurred when the GP aborted the questionnaire before completing the registration (N=4), when the GP declared that he/she was unable to produce the ultrasound images due to e.g. bowel gas (N=13) or in cases where the time separation between before and after registrations was below one minute. In these cases, we assumed there was no separation between the registrations and the before registration was deleted (N=29).

Questions BEFORE the use of POC-US:

Question number	Question	Possible answers
PQ 1.1	GP ID number	GPxx
PQ 1.2	Patient ID number	Pxxx
PQ 1.3	Date	Dxxxxxxxx
PQ 1.4	Patient gender	Male/female
PQ 1.5	Patient Age	xxx years
Q 1.1	What is the main reason to use POC-US in this patient?	Rule-in/Rule-out Explore
Q 1.2	Which organs/positions do you expect to scan?	Organs on list
Q 1.3	What is the main tentative diagnosis for this patient?	ICPC2 codes
Q 1.4	Are there any other possible tentative diagnoses in this case?	ICPC2 codes
Q 1.5	What is your overall plan for this patient?	Acute admission to hospital Subacute referral to hospital Elective referral hospital Subacute referral to specialist Elective referral to specialist Referral to radiology Other referral e.g. physiotherapist Follow-up in the clinic No plan for follow-up Other
Q 1.6	Which treatment will you initiate at this stage?	Medication I will refer for treatment I will initiate other treatment None Other

Questions AFTER the use of POC-US:

Question number	Question	Possible answers
Q 2.1	How much time did you use on the POC-US examination?	Minutes
Q 2.2	Which organs/positions did you scan?	Organs in drop-down menu
Q 2.3	Were you able to produce ultrasound images of the relevant structures of (inserted text) ?	Yes No – why not?
Q 2.4	What did you find?	Certain positive findings

		Uncertain positive findings Certain negative findings Uncertain negative findings Incidental findings – please specify in free text
Q 2.5	Before POC-US you registered these tentative diagnoses (inserted text) Have your tentative diagnoses changed?	Yes, the diagnoses have changed but the ICPC2 codes are the same Yes, the diagnoses have changed and the ICPC2 codes have also changed No*
Q 2.6	What is the tentative diagnosis for this patient now?	ICPC2 codes
Q 2.7	Are there any other possible tentative diagnoses for this patient (please specify)?	ICPC2 codes
Q 2.8	How is your confidence in your main tentative diagnosis, after you have used POC-US?	Highly increased confidence More confidence unchanged confidence Less confidence Highly reduced confidence.
Q 2.9	Before POC-US you registered this plan (inserted text) for the patient. Has your overall plan changed?	Yes No**
Q 3.0	What is your overall plan for this patient, now?	Acute admission to hospital Subacute referral to hospital Elective referral hospital Subacute referral to specialist Elective referral to specialist Referral to radiology Other referral e.g. physiotherapist Follow-up in the clinic No plan for follow-up Other
Q 3.1	Before POC-US you registered this treatment (inserted text) for the patient. Has your initiated treatment for this patient changed?	Yes No*
Q 3.2	Which treatment will you initiate at this stage?	Medication I will refer for treatment I will initiate other treatment None Other

* Move on to Q2.8
** Move on to Q3.1

Appendix 4: ICPC2 codes registered in the study

Diagnoses registered according to the international classification of primary care 2nd edition (ICPC2)[1].

SYMPTOMS/COMPLAINTS
INFECTIONS
NEOPLASMS
INJURIES
CONGENITAL ANOMALIES
OTHER DIAGNOSES

General and Unspecified A

ICPC2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
A08 Swelling	8				1		
A26 Fear of cancer NOS	1						
A77 Viral disease other/NOS					1		
A79 Malignancy NOS						1	
A85 Adverse effect medical agent		2			1	1	
A94 Perinatal morbidity other		1					
A97 No disease					1		
A98 Health maintenance/prevention	1					1	

Blood, Blood Forming Organs and Immune Mechanism B

ICPC2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
B02 Lymph gland(s) enlarged/painful	5				1		
B27 Fear blood/lymph disease other					1		
B76 Ruptured spleen traumatic	1				1		

Digestive D

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
D01 Abdominal pain/cramps general	7				3		
D02 Abdominal pain epigastric	5	1			3		
D06 Abdominal pain localized other	9	1			3	1	
D07 Dyspepsia/indigestion	2	2			3		
D08 Flatulence/gas/belching	1						
D11 Diarrhoea	1				1		
D12 Constipation	1	1	1		2		
D21 Swallowing problem	1				1		
D23 Hepatomegaly	1						
D24 Abdominal mass	2	1			1		
D25 Abdominal distension	2				2		
D27 Fear of digestive disease other					1		
D73 Gastroenteritis presumed infection		2			1	2	
D75 Malignant neoplasm colon/rectum						1	
D77 Malig. neoplasm digest other						1	1

D78 Neoplasm digest benign/uncertain					1		
D84 Oesophagus disease					1		
D86 Peptic ulcer other					1		
D88 Appendicitis	1	1			1		
D89 Inguinal hernia	1				1		
D91 Abdominal hernia other					1		
D92 Diverticular disease	1	1		1	3	1	
D93 Irritable bowel syndrome					2		
D97 Liver disease NOS		1			1		
D98 Cholecystitis/cholelithiasis	14	5			9	4	
D99 Disease digestive system, other		1					

Cardiovascular K

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
K02 Pressure/tightness of heart	1						
K04 Palpitations/awareness of heart	1						
K06 Prominent veins		1				1	
K07 Swollen ankles/oedema	1				2	1	
K22 Risk factor cardiovascular disease	1				1		
K24 Fear of heart disease	1	1			1	1	
K27 Fear cardiovascular disease other					1		
K28 Limited function/disability (k)	1						
K29 Cardiovascular sympt./complt. other							
K77 Heart failure	9	6			4	2	
K78 Atrial fibrillation/flutter		2				1	
K79 Paroxysmal tachycardia					1		
K84 Heart disease other	5				1	2	
K85 Elevated blood pressure					1		
K86 Hypertension uncomplicated			1		16		1
K87 Hypertension complicated					1		
K92 Atherosclerosis/PVD	4				3		
K93 Pulmonary embolism	1						
K94 Phlebitis/thrombophlebitis	7	3			2		
K95 Varicose veins of leg	2	2			5		
K99 Cardiovascular disease other	17	4			3		

Musculoskeletal L

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
L02 Back symptom/complaint	1	1	1		2	1	
L04 Chest symptom/complaint	3	1			2		
L05 Flank/axilla symptom/complaint	2				1		
L08 Shoulder symptom/complaint	25	2			11	1	
L09 Arm symptom/complaint	3				2		
L10 Elbow symptom/complaint	3				4		
L11 Wrist symptom/complaint	1				1		
L12 Hand/finger symptom/complaint	2				2		
L13 Hip symptom/complaint	5				2		
L14 Leg/thigh symptom/complaint	3	1			3		
L15 Knee symptom/complaint	18	1			11	1	
L16 Ankle symptom/complaint	3				3		
L17 Foot/toe symptom/complaint	6				5		
L18 Muscle pain	2			1	1		
L19 Muscle symptom/complaint NOS	1	3			2	1	
L20 Joint symptom/complaint NOS	4				3	1	

L70 Infections musculoskeletal system		1					
L72 Fracture: radius/ulna	1				1		
L74 Fracture: hand/foot bone		1					
L76 Fracture: other	6				4		
L77 Sprain/strain of ankle		1				1	
L78 Sprain/strain of knee	2	1			4		
L79 Sprain/strain of joint NOS	1	1			2	2	
L80 Dislocation/subluxation				1	1		
L81 Injury musculoskeletal NOS	3	3			5	2	
L84 Back syndrome w/o radiating pain	1				1		
L86 Back syndrome with radiating pain					1		
L87 Bursitis/tendinitis/synovitis NOS	52	11	1		67	7	
L90 Osteoarthrosis of knee	1	2			2	2	
L91 Osteoarthrosis other	3	1			4	1	
L92 Shoulder syndrome	7	5	1		15	4	
L93 Tennis elbow	2				2		
L96 Acute internal damage knee		1				1	
L97 Neoplasm benign/unspec musculo	1				2		
L99 Musculoskeletal disease, other	1		1		1		1

Neurological N

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
N06 Sensation disturbance other		1			1		
N82 (scannede nyre –positivt fund)– evt R82??					1		

Psychological P

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
P01 Feeling anxious/nervous/tense					1		
P02 Acute stress reaction					2		

Respiratory R

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
R01 Pain respiratory system	1				1		
R02 Shortness of breath/dyspnoea	6				8		
R04 Breathing problem	1	1			1	1	
R05 Cough	1				3		
R21 Throat symptom/complaint					3		
R27 Fear of respiratory disease	1				2		
R29 Respiratory symptom/complaint oth	1						
R74 Upper respiratory infection acute		5			1	1	
R78 Acute bronchitis/bronchiolitis		6			1	4	
R80 Influenza		1			1		
R81 Pneumonia	17	1			11		
R82 Pleurisy/pleural effusion	4	2	1		4	1	
R84 Malignant neoplasm bronchus/lung	1				1		
R88 Injury respiratory other		1					
R91 (1. kode pleurit) måske det skulle være R92?		1			1		
R95 Chronic obstructive pulmonary dis		3	1		2	3	

R96 Asthma		2			2		
R99 Respiratory disease other	1			1			

Skin S

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
S04 Lump/swelling localized	5	2			2	1	
S05 Lumps/swellings generalized	1				1		
S10 Boil/carbuncle	4	4			2	2	
S15 Foreign body in skin	2				1		
S16 Bruise/contusion	1	2	1		3	1	1
S18 Laceration/cut					1		
S76 Skin infection other	3	1			8		
S78 Lipoma	2	1	1		5	1	1
S93 Sebaceous cyst					2		
S99 Skin disease, other					1		

Endocrine/Metabolic and Nutritional T

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
T01 Excessive thirst		1				1	
T07 Weight gain		1					
T08 Weight loss	1				1		
T11 Dehydration						1	
T81 Goitre	3	1			2		
T92 Gout	3				2		
T99 Endocrine/metab/nutrit. dis. other	1	2			1	1	

Urological U

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
U01 Dysuria/painful urination	1				1		
U02 Urinary frequency/urgency	1				1		
U04 Incontinence urine	1				1		
U05 Urination problems other	2				2		
U06 Haematuria	2	1					1
U07 Urine symptom/complaint other					1		
U08 Urinary retention	8	2	1		8	2	
U13 Bladder symptom/complaint other	1	1			1		
U14 Kidney symptom/complaint	2						
U70 Pyelonephritis/pyelitis		2					
U71 Cystitis/urinary infection other	5	2	2		11	2	1
U78 Benign neoplasm urinary tract	1				1		
U79 Neoplasm urinary tract NOS					1		
U95 Urinary calculus	6	1			4	3	
U99 Urinary disease, other	5	5	1		2	3	

Pregnancy, Childbearing, Family Planning W

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
W03 Antepartum bleeding	3						
W11 Contraception oral	2				2		
W12 Contraception intrauterine	41	3	1		40	2	1
W15 Infertility/subfertility					1		
W18 Post-partum symptom/complaint oth.					1		
W27 Fear complications of pregnancy	3				1		
W29 Pregnancy symptom/complaint other	2				1		
W30	1				2		
W71 Infection complicating pregnancy		1					1
W72 Malignant neoplasm relate to preg.	1				1		
W78 Pregnancy	58	4			62	1	
W80 Ectopic pregnancy	1	3	1			2	
W82 Abortion spontaneous	4	3			2		
W83 Abortion induced	1				1		
W84 Pregnancy high risk	2	1			3	1	
W96 Complications of puerperium other	1						

Female Genital X

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
X01 Genital pain female	1	1	1			1	1
X05 Menstruation absent/scanty	2				1		
X06 Menstruation excessive	3				2		
X07 Menstruation irregular/frequent	1	1			2	1	
X08 Intermenstrual bleeding	3				1		
X11 Menopausal symptom/complaint	1				1		
X12 Postmenopausal bleeding	2	1			2	1	
X13 Postcoital bleeding	2				1		
X14 Vaginal discharge	1	1				1	
X15 Vaginal symptom/complaint other	1				1		
X17 Pelvis symptom/complaint female	5				4		
X19 Breast lump/mass female	2	1			1		
X25 Fear of genital cancer female	1				1		
X27 Fear genital/breast disease other (f)	1				1		
X28 Limited function/disability (x)					1		
X29 Genital symptom/complt female oth.					1		
X72 Genital candidiasis female					1		
X74 Pelvic inflammatory disease		2					
X77 Malignant neoplasm genital other (f)					2	1	
X78 Fibromyoma uterus		1	1		4	1	
X79 Benign neoplasm breast female		1				1	
X80 Benign neoplasm female genital		1		1	3		
X81 Genital neoplasm oth/unspecied (f)		1					
X84 Vaginitis/vulvitis NOS						1	
X87 Uterovaginal prolapse	1				1	1	
X92 Chlamydia infection genital (f)						1	
X99 Genital disease female, other	4	2			6	1	

Male Genital Y

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
Y02 Pain in testis/scrotum	2				1		

Y74 Orchitis/epididymitis					1		
Y82 Hypospadias	1				1		
Y85 Benign prostatic hypertrophy			1	1		1	1

(1) The World Organization of Family Doctors' (WONCA) International Classification Committee (WICC). International Classification of Primary Care. 2015; Available at: https://www.globalfamilydoctor.com/site/DefaultSite/filesystem/documents/Groups/WICC/International%20Classification%20of%20Primary%20Care%20Dec16.pdf. Accessed 14 oct, 2019.

Appendix 5. Changes in registered tentative diagnoses codes before and after ultrasonography

N=528	Registrations before ultrasound Number (%)	Registrations after ultrasound Number (%)	Ultrasound entailed a more specific diagnosis
Number of patients with 1 ICPC2 code	371 (70.3)	436 (82.6)	The number of patients with >1 ICPC2 code was reduced from 29.6% to 17.5%
Number of patients with 2 ICPC2 codes	138 (26.1)	81 (15.3)	
Number of patients with 3 ICPC2 codes	13 (2.5)	11 (2.1)	
Number of patients with 4 ICPC2 codes	6 (1.1)	0 (0.0)	
Symptoms/complaints codes	249 (47.2)	193 (36.6)	The number of patients with symptom codes reduced while the number of patients with disease specific ICPC2 codes increased
Infection codes	33 (6.3)	43 (8.1)	
Neoplasms codes	6 (1.1)	21 (4.0)	
Injuries codes	17 (3.2)	24 (4.5)	
Congenital anomalies codes	1 (0.2)	1 (0.2)	
Other diagnoses codes	221 (41.9)	244 (46.2)	
Wrong code	0 (0.0)	2 (0.4)	

* Wrong code = Registered code in the questionnaire that did not translate into the ICPC2 coding system.
ICPC2= international Classification of primary care 2nd edition [18]

Appendix 6: Change in patient care after ultrasonography

	Before registrations	After registrations
Change in the intended plan for the patient		
Acute admission to hospital	10	12
Subacute referral to hospital	32	16
Elective referral hospital	50	32
Subacute referral to specialist	18	7
Elective referral to specialist	64	38
Referral to radiology	86	30
Other referral e.g. physiotherapist (primary care services)	20	32
Follow-up in the clinic	165	183
No plan for follow-up	106	198
Change in the intended treatment of the patient		
I will initiate medication	104	107
I will refer for treatment	87	68
I will initiate other treatment	64	115
I will not initiate treatment	283	277
Other	4*	11*

Comparison between complete before and after registrations (N=528)
The questions was designed as multiple choice. Results are provided as the number of registrations.
* Referral for treatment in physiotherapy

Manuscript according to the Strobe-checklist

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5 Appendix 2 Appendix 3
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5 Published Statistical analysis plan
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	Appendix 3
		(*d*) If applicable, explain how loss to follow-up was addressed	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	Table 1 Figure 1 -
Outcome data	15*	Report numbers of outcome events or summary measures over time	-
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	6-7 Figure 3 + 4
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

The use and impact of point-of-care ultrasonography in general practice: a prospective observational study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-037664.R1
Article Type:	Original research
Date Submitted by the Author:	12-Jun-2020
Complete List of Authors:	Aakjær Andersen, Camilla ; Aalborg Universitet, Center for General Practice at Aalborg University Brodersen, John; University of Copenhagen, Centre of Research & Education in General Practice, Department of Public Health, Faculty of Health Sciences; Primary Health Care Research Unit, Zealand Region Davidsen, Annette Sofie; University of Copenhagen, Research Unit for General Practice and Section of General Practice Department of Public Health, Faculty of Health Sciences Graumann, Ole ; Odense Universitetshospital, Department of Radiology, Radiological Research and Innovation Unit Jensen, Martin Bach; Aalborg Universitet, Center for General Practice af Aalborg University
Primary Subject Heading:	General practice / Family practice
Secondary Subject Heading:	Diagnostics, Health services research, Radiology and imaging
Keywords:	PRIMARY CARE, ULTRASONOGRAPHY, Change management < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT

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The use and impact of point-of-care ultrasonography in general practice: a prospective observational study.

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Wordcount: 3064

Abstract

Objectives: To describe how general practitioners (GPs) use point-of-care ultrasonography (POCUS) and how it influences the diagnostic process and treatment of patients.

Design: Prospective observational study using an online questionnaire before and after POCUS.

Setting: Office-based general practice.

Participants: Twenty GPs consecutively recruited all patients examined with POCUS in one month.

Primary and secondary outcome measures: We estimated the use of POCUS through the indication for use, the frequency of use, the time consumption, the extent of modification of the examination, and the findings.

The influence on the diagnostic process was estimated through change in the tentative diagnoses, change in confidence, the ability to produce ultrasound images, and the relationship between confidence and organs scanned or tentative diagnoses.

The influence of POCUS on patient treatment was estimated through change in plan for the patient, change in patient's treatment, and the relationship between such changes and certain findings.

Results: The GPs included 574 patients in the study. POCUS was used in patient consultations with a median frequency of 8.6% [IQR: 4.9-12.6]. Many different organs were scanned covering more than 100 different tentative diagnoses. The median time taken to perform POCUS was 5 minutes [IQR: 3-8]. Across applications and GPs, POCUS entailed a change in diagnoses in 49.4% of patients; increased confidence in a diagnosis in 89.2% of patients; a change in the management plan for 50.9% of patients including an absolute reduction in intended referrals to secondary care from 49.2% to 25.6%; and a change in treatment for 26.5% of patients.

Conclusions: The clinical utilization of POCUS was highly variable amongst the GPs included in this study in terms of the indication for performing POCUS, examined scanning modalities, and frequency of use. Overall, using POCUS altered the GPs' diagnostic process and clinical decision-making in nearly three out of four consultations.

Trial registration: Clinical trials registration number: NCT03375333

Strengths and limitations of this study

This study explores the use of point-of-care ultrasound in a broader sample of general practitioners.

The study was developed through a comprehensive qualitative work and designed to mimic daily practice.

This study may be subject to selection bias since the participating GPs likely constitute a subset of physicians with a special interest in ultrasonography.

The study registrations were time-consuming and fewer patients than expected were included.

Point-of-care ultrasound changed diagnosis, plan and/or treatment for most patients, but we did not evaluate whether these changes improved or worsened patient care.

Introduction

Point-of-care ultrasound (POCUS) is used in general practice in several countries.[1-4] A recent systematic review found that few studies described the use of POCUS in the hands of the general practitioner (GP) and that obstetric, abdominal, and heart examinations were the most commonly described.[5] The included studies, however, focused on selected scanning modalities and largely aimed to explore a possible transition of ultrasound examinations from secondary to primary care. The recent introduction of POCUS, as something disparate from ultrasound examinations performed by radiologists or other highly specialised physicians[6,7], prepares the ground for more widespread use, as it encourages clinicians to apply POCUS as part of the physical examination of patients.[8,9] Hence, the current use of POCUS in general practice may differ from use previously reported. No previous studies have quantified the use of POCUS in a larger group of GPs with different types of ultrasound training, who have adopted the technology without either constraining or supporting guidelines and without financial incentives.

Evidence from the secondary healthcare sector has shown that certain POCUS applications affect the diagnostic process leading to earlier and more correct diagnosis,[10,11] a subsequent change in patient treatment, and a more rational use of healthcare resources.[12,13] A few recent studies from general practice suggest the same.[14-16] However, little attention has been given to the specific impact of POCUS on the diagnostic process in general practice and GPs' clinical decision making.

The aim of this study was to describe how GPs use POCUS in their daily practice and how it influences the diagnostic process and the treatment of patients.

Method

Study design

This prospective observational study was registered in clinical trials (registration number: NCT03375333) prior to recruiting participants. We report the study findings according to STROBE guidelines.

Study setting

The study was conducted in office-based general practices in Denmark, where GPs were already using POCUS. Denmark has universal, publicly funded health care system, where almost all patients are registered with a GP. The GPs act as gatekeepers for secondary care services including ultrasonography. GPs receive no fee for performing POCUS in primary care.

Participating general practitioners

Twenty GPs were recruited through POCUS networks, conferences, and teaching sessions (Appendix 1). To be included in the study, GP had to:

- Have used POCUS for a more than six months
- Use POCUS for a minimum of two anatomical areas
- Use POCUS on a daily basis
- Have participated in formalized POCUS training e.g. an ultrasound course
- Work in a practice with a patient population over 1400
- Work in the practice minimum four days a week.

GPs with an ultrasound system more than 10 years old or with any possible financial conflict of interest were excluded. The GPs were enrolled in the study stepwise from January 2018 to August 2018 to account for any seasonal variation in POCUS examinations. Prior to the study, participating GPs' POCUS

competences were assessed using a modified version of the Objective Structured Assessment of Ultrasound Skills (OSAUS)[17] and an objective structured clinical examination (OSCE) evaluation sheet (Appendix 2). The GPs were blinded to the results of this assessment.

Participating patients

All patients who sought care for conditions that the participating GP found relevant for POCUS examination were invited to participate in the study.

Data collection and study procedure

The GPs consecutively registered information on all POCUS examinations during one month (20 to 25 working days), while performing POCUS according to their usual indications and standards and using their own ultrasound systems. When a GP planned to use POCUS, the patient received study information and a written informed consent was obtained. Thereafter the GPs accessed an online SurveyXact questionnaire (Rambøll, Aarhus, Denmark) and completed items before and after conducting POCUS. A time log measured the time between the before and the after POCUS registrations. (See Appendix 3 for questionnaire details).

We also registered the total number of face-to-face patient consultations during the study period and the number of eligible patients who were not included due to e.g. time constraints. The primary investigator (CAA) visited the GPs' clinics on the first day of inclusion to help with the registrations and to perform a validity test of the GPs' registration.

Outcome measures

The use of POCUS in general practice was estimated through: (1) the indication for using POCUS; (2) the frequency of POCUS; (3) the time consumption for POCUS; (4) the extent of modification of the POCUS; and (5) the POCUS findings.

The influence of POCUS on the diagnostic process in general practice was estimated through: (1) change in the tentative diagnoses according to the international classification of primary care 2nd edition (ICPC2)[18] before and after POCUS; (2) The GP's declared change in confidence in the main tentative diagnosis after the use of POCUS; (3) The GP's ability to technically produce ultrasound images; (4) the relationship between confidence in the main tentative diagnosis and the examined scanning modalities, reduction in the number of tentative diagnoses, and change from symptom to disease-specific diagnoses.

The influence of POCUS on patient treatment in general practice was estimated through: (1) change in plan for the patient; (2) change in patient's treatment; (3) the relationship between certain findings and changes in the management plan or treatment of the patient.

Sample size and statistical analysis

Based on a questionnaire study[3], we estimate that there were around 75 GPs in Denmark, who would meet our inclusion criteria. We found it realistic to include 20 of the GPs in the study. Based on an interview study with Danish GPs[16], we estimated that the GPs would use POCUS 2-3 times a day. Assuming a participation rate of 80%, we expected to include 640 to 960 patients during the study period of one month.

Data was analysed using STATA V.15.0 (StataCorp, College Station, Texas, USA) according to a predefined analysis plan (Clinical trials registration number: NCT03375333). Categorical variables were

summarised using absolute frequencies and continuous variables using mean and standard deviation (median and interquartile range if not normally distributed). Relative-risk reduction in referrals for secondary care was calculated by considering referrals as events, the before-POCUS registrations as controls and the after-POCUS registrations as interventions. Our predefined hypotheses, all published in clinical trials, about the relationship between variables were analysed using Fishers exact test and a significance level of 0.05

Ethical approval

Written informed consent was obtained from all participating GPs and patients and all data were pseudo-anonymised using de-identification numbers. Only the principal investigator (CAA) knew the identity of the GPs and only the GPs knew the identity of the participating patients. The study was approved by the Danish Data Protection Agency and the Committee of Multipractice Studies. The study was also notified to the Regional Committee on Health Research Ethics, but they responded that their approval was not needed according to Danish law.

Patient and public involvement statement

Patients were involved and invited to provide feedback during the design and pilot testing of the registration tools used in this study.

Results

Twenty general practitioners from 18 clinics each enrolled a median of 26 [IQR 17- 40] patients. Data from 574 patients were available for analysis, and in 528 patients data were available for before-after comparison (Figure 1). Background characteristics are given in Table 1.

POCUS competences were assessed in 19 GPs covering between two and six applications, depending on their normal use of POCUS (Figure 2 and Appendix 2).

The use of POCUS

Each GPs performed between 12 and 84 POCUS examinations (median: 32.0 [IQR: 17.8-42.8]) corresponding to an individual average between 0.6 and 3.9 ultrasound examinations per day. The GPs had between 13.0 and 24.4 face-to-face patient consultations per day (median: 15.9 [IQR: 14.2-17.8]). Hence, during the study period each GPs performed POCUS in between 3.7% and 20.8% of all face-to-face consultations [median: 8.6 [IQR: 4.9-12.6]).

When GPs were using POCUS they aimed primarily to confirm or disconfirm a specific clinical condition (73.1%), or to explore the reason for the patient's symptoms without having a specific clinical condition in mind (20.2%), but they rarely planned to do both (1.6%). A total of 126 different ICPC2 codes were registered as the primary tentative diagnosis before the use of POCUS (Appendix 4).

POCUS was used to examine many different organs and structures (Figure 3). The GPs registered examining a total of 834 scanning modalities in 570 POCUS examinations (data missing in 4 patients); most commonly heart and lung in combination and different combinations of abdominal organs. In addition, we found that GPs modified their POCUS examination to include more scanning modalities than intended in 15.5%, and fewer scanning modalities than intended in 8.0% of all ultrasound examinations.

The median time consumption for the POCUS examination was 5 minutes [IQR: 3-8] but varied from 1 to 30 minutes (Figure 3).

Images of the relevant structures could be produced in between 95% and 100% of the applications, though some seemed to cause more difficulty: lymph nodes (75%); pancreas (75%); ovaries (78%); heart (89%); kidney (93%), and others (86%).

The GPs classified their POCUS examinations to include: certain positive findings (45.7%); uncertain positive findings (9.3%); certain negative findings (32.3%); uncertain negative findings (10.2%), and different combinations of these findings (1.7%). In addition, the GPs registered incidental findings in six patients.

POCUS influence on the diagnostic process

POCUS changed the main tentative diagnosis in 49.4% of consultations (Table 2 and Appendix 4). This encompassed a reduction in the number of patients where the GP had more than one tentative diagnosis from 29.6% before to 17.5% after the POCUS examination. There was also a reduction in the number of symptom diagnoses and a corresponding increase in the number of disease-specific, infection-related, cancer-related and emergency-related diagnoses after as compared to before the POCUS examination (Appendix 5).

After POCUS, the GPs declared the following change in their confidence in the primary tentative diagnosis: highly increased confidence (60.5%); increased confidence (28.5%); unchanged confidence (6.6%); reduced confidence (1.0%), and highly reduced confidence (0.1%). Seven consultations entailed reduced confidence, the applications in these examinations were: heart (1), lung (1), thyroid and lymph nodes (1), subcutaneous process (1), gallbladder, liver and pancreas (1), tendon (1) and uterus (1). Increased confidence did not seem to depend on area of POCUS application as we found no variation beyond what could be expected by chance (0.082). Likewise, no relationship was found between a reduction in the number of tentative diagnosis and increased confidence (P = 0.127). We did, however, find a relationship between increased confidence and a change from symptom diagnosis to disease-specific diagnosis (P = 0.037).

POCUS influence on patient treatment

POCUS changed the intended management plan for patients in 50.9% of consultations (Table 2), including a reduction in the absolute number of patients referred to hospital or secondary care clinics from 174 (33.0%) to 105 (19.9%) patients, and a reduction in the number of patients referred for imaging in the secondary sector from 86 (16.3%) to 30 (5.7%). Overall, there was an absolute reduction in intended referrals for secondary care from 49.2% to 25.6% corresponding to an absolute risk reduction of 23.6% and a relative-risk reduction of 48.0%, Correspondingly, the number of patients with planned follow-up in primary care increased from 185 (35.0%) to 215 (40.7%), and patients with no planned follow-up increased from 106 (20.1%) to 198 (37.5%) following POCUS (Table 3).

After POCUS, the intended treatment was changed in 26.5% of consultations (Table 2). The number of patients planned for referral to treatment in the secondary sector fell from 87 (16.4%) to 63 (11.9%). The number of patients where the GP would not initiate treatment fell from 283 (53.6%) to 269 (50.9%); whereas the number of patients where the GP initiated treatment increased from 168 (31.8%) to 208 (39.4%) (Table 3). We found no relationship between the GPs' classification of certain findings and a change in the patient's plan (p=0.913), or change in the patient's treatment (p=0.214).

Overall change as a result of POCUS (change in diagnosis and/or change in the patient's plan and/or change in the patient's treatment) was found in 71.8 % of consultations (Table 2).

Discussion

Summary of main findings

This study showed that across applications POCUS had a large impact on the diagnostic process in general practice. POCUS changed the tentative diagnoses in 49.4% of patients and increased confidence in the main tentative diagnosis in 89.2% of patients. POCUS changed the intended management plan in 50.9% of patients, including a relative-risk reduction in planned referrals of 48%, and a change in the intended treatment of 26.5% of patients.

Strengths and limitations

This study had a broader sample of scanning GPs than most reported studies. Furthermore, the registration tool was developed through comprehensive qualitative work[16] and pilot testing. We designed the study to mimic daily work and to avoid recall-bias in the registrations. Furthermore, the GPs were blinded to the results of their competence evaluations.

We included fewer patients than expected. The patient information and study registrations added 10 minutes to the consultation and, due to time constraints, GPs may have chosen not to perform some POCUS examinations. Hence the frequency of POCUS reported in this study may be underestimated.

The participating GPs varied considerably in their background characteristics, but given their interest in POCUS, they most likely constitute a select group compared to a broader population of GPs. The participating GPs resembled the general GP population in Denmark in terms of the location and size of the clinic, but not in terms of age, gender or organisation of the clinic. Specifically, the participants were younger, more often male and more often working in a partnership practice[19]. Being a selected group of early-adapters of the technology, it is plausible that the participating GPs rely heavily on POCUS in their daily work and subsequently that the frequency of increased confidence and change in diagnosis, plan or treatment is higher in this particular group of GPs.

We used Fishers exact test to explore overall associations. Due to the lack of statistical power, however, no firm conclusions can be made regarding the relationship between the GP's confidence in the main tentative diagnosis and the organs scanned.

Findings in context

In line with previous research[2,5,20] we found large variation in the application of POCUS in general practice. The most common applications in this study were pelvic and musculoskeletal POCUS. This may be explained by the fact that all participating GPs had received training in pelvic POCUS and all but two had participated in a musculoskeletal POCUS course. Another explanation may relate to patient encounters in Danish general practice. A previous qualitative study has described how Danish GPs perform POCUS examinations that they consider relevant in their patient population[16] and musculoskeletal conditions are the most common organ-specific complaints raised by patients in Danish general practice.[21] Moreover, in a recent needs-assessment, pelvic ultrasound was found to be the POCUS application GPs had most interest in learning.[22]

This study illustrates that POCUS is used to support the physical examinations of patients presenting with a very broad range of clinical conditions. There have been attempts to outline which POCUS examinations are best suited to general practice.[4,20,22-25] The evidence base for these attempts is sparse, however, and there may be significant differences between countries regarding which examinations are most relevant.[3] In addition, some examinations may be easier to master than others[5], both in terms of

achieving competence and in terms of maintaining competence over time. The latter may be particularly important in general practice where the frequency of some POCUS examinations is as low as shown in this study (Figure 3). Some studies have reported high diagnostic accuracies of GPs' POCUS examinations, when these were compared to repeated scans by imaging specialists[15,26]. However, these studies only included few scanning modalities, a rather small number of GPs, and the evaluation of accuracy was made shortly after participation in a training programme. Hence, we do not know if the results would be equally good if POCUS was applied for more applications, in a wider selection of GPs, or if long-term proficiency is achievable. Determining whether POCUS use in general practice results in better patient outcomes should include an evaluation of both the diagnostic accuracy (including potential overdiagnosis) of the performed examinations as well as the medical decision-making following the scan. In our baseline evaluation of the GPs scanning competences, we found that a few of the GPs lacked the practical skills for performing the scans, despite using POCUS regularly and having participated in training (Figure 2). Likewise, we found that the GPs described their POCUS findings as uncertain in 19.7% of examinations. Office-based GPs may be used to navigating in uncertainty and performing up to a certain level before referring patients on to more advanced care. Still, POCUS is a particularly user-dependent technology[23,27] and the ability to rule-in or rule-out, as well as the prevalence and interpretation of incidental findings, may differ between applications.[5,28.] Thus, there is a need for more research and evidence-based guidelines to support GPs in choosing what to scan and how to integrate findings into clinical care.

Previous studies from hospitals have shown that some POCUS examinations entail a change in patient care[10,11,29-31] and our study suggests that this finding also applies in primary care. The GPs' registration data showed that 49.2% of patients would have had onward referral if POCUS had not been available. This referral frequency was reduced from 49,2% to 25.6% by using POCUS, whereas the number of patients with planned follow-up in general practice, or no follow-up, increased. Previous studies from general practice have suggested a reduction in referrals,[14,32] but how POCUS in general practice affects overall healthcare costs is unknown.

Implications for practice

POCUS was used in in the patient consultation with a median of 8.6% and with a median time consumption of five minutes. Hence, the use of POCUS is feasible in general practice despite differences in ultrasound equipment, experience, educational background, and choice of examinations. POCUS largely impacted diagnostic certainty and patient management. It remains to be investigated, if the change in patient management caused by POCUS actually improves patient care, or if it causes harm in terms of false positive findings, misdiagnosis, over-detection, and potential, subsequent overtreatment.

Conclusion

POCUS examinations in general practice were used for many different indications and entailed an increased diagnostic reassurance for the GP and a change in diagnosis or management in 71.8% of patients. The potential high impact of POCUS underlines the need for further research to support an appropriate implementation of POCUS in general practice.

List of abbreviations

POCUS = Point-of-Care Ultrasonography

GP = General practitioner

OSAUS = Objective Structured Assessment of Ultrasound Skills

OSCE= Objective structured clinical examination

ICPC2= The international classification of primary care 2nd edition

Acknowledgements

The authors would like to thank the participating GPs for their individual contributions and the Danish Society for Ultrasound in General Practice (DAUS) for non-financial support of the study.

Conflict of interest statement

The authors report no conflicts of interest.

Funding statement

This study was conducted as independent research financially supported by the Committee of Multipractice Studies in General Practice and The Danish Research Foundation for General Practice.

Author contributions

CAA, JB, ASD, OG and MBJ all participated in designing the study and developing the registration tools. CAA recruited and instructed the participating GPs prior to the study. OG performed the evaluation of the participating GPs POCUS competences. Data collection and analysis was performed by CAA and MBJ. CAA wrote the first draft of the article in collaboration with MBJ. All authors participated in the following review process and contributed to the final version of the article.

Data availability statement

All study data are safely stored at Center for General practice at Aalborg University in Denmark and available upon reasonable request to the corresponding author.

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Table 1. Background characteristics

Characteristics of the clinics N=18		Characteristics of the GPs N=20		Characteristics of the patients N=574*	
Location in Denmark		**Age**		**Age**	
North Denmark Region	4(22.2)	< 40 years	2(10.0)	< 30 years	98(17.1)
Central Denmark Region	3(16.7)	40-50 years	14(70.0)	30-50 years	198(34.5)
Region of Southern Denmark	5(27.8)	51-60 years	3(15.0)	51-70 years	188(32.8)
Region Zealand	2(11.1)	> 60 years	1(5.0)	> 70 years	90(15.7)
Capital Region of Denmark	4(22.2)	Mean: 46.2 (95%CI: 43.2-49.1) years		Mean: 49.7 (95%CI: 48.2-51.1) years	
Location classified by the GP		**Gender**		**Gender**	
Urban	10(55.6)	Male	14(70.0)	Male	191 (33.3)
Mixed	6(33.3)	Female	6(30.0)	Female	383 (66.7)
Rural	2(11.1)				
Practice size		**Experience as a general practitioner**			
< 2000 patients	3(16.7)	< 10 years	12(60.0)		
2000-5000 patients	9(50.0)	10–20 years	7(35.0)		
> 5000 patients	6(33.3)	> 20 years	1(5.0)		
Type of practice		**Experience using ultrasonography**			
Partnership practice	15(83.3)	< 2 years	6(30.0)	* For comparison, excluded patients (N= 117) were 29.1% male and with a mean age of 43.2 (95%CI: 38.9-47.5) years.	
Solo-practice	1(5.5)	2-5 years	11(55.0)		
Collaboration practice	2(11.1)	> 5 years	3(15.0)		

Number (percentage) of the total number of participants in each group (N)

Table 2. Change in diagnosis, management plan, or treatment following the use of point-of-care ultrasonography

POCUS application*	N	Change in the tentative diagnoses, *n (%)*	Change in the intended management plan *n(%)*	Change in the intended treatment *n (%)*	Overall Change**, *n (%)*
Heart	34	23 (68)	20 (59)	10 (29)	29 (85)
Lung	44	26 (59)	23 (52)	15 (34)	37 (84)
Upper Abdomen.	36	22 (61)	17 (47)	11 (31)	25 (69)
Urinary tract	67	41 (61)	35 (52)	20 (30)	50 (75)
Obstetric and gynecological	165	61 (37)	83 (50)	35 (21)	97 (59)
Ascites	15	10 (67)	9 (60)	8 (53)	10 (67)
Aorta	29	25 (86)	11 (38)	5 (17)	26 (90)
Deep vein thrombosis	13	10 (77)	10 (77)	4 (31)	12 (92)
Musculoskeletal	157	76 (48)	90 (57)	55 (35)	124 (79)
Subcutaneous process	31	16 (52)	18 (58)	10 (32)	22 (71)
Thyroid	6	4 (67)	1 (17)	1 (17)	5 (83)
Other	40	21 (53)	18 (45)	7 (18)	26 (65)
Total	**528**	**261 (49)**	**269 (51)**	**140 (27)**	**379 (72)**

POCUS= Point-of-care ultrasonography

* The following registered scanning modalities are categorized according to POCUS application: *Upper abdominal organs* (including liver, gall bladder, pancreas), *Urinary tract* (including kidney, and bladder), *Obstetric and gynecological* (including uterus, ovaries, placenta, foetus, and fossa douglasi), *Musculoskeletal* (including joints, muscle, tendon, bone, and joint puncture) The *others* category includes free text answers and registered applications with a frequency below five examinations.

** Overall change includes change in either diagnoses, management plan and/or treatment.

Table 3. Registered change in patient care following the use of point-of-care ultrasonography.

	Before registrations *n*	After registrations *n*
Change in the intended plan for the patient		
Acute admission to hospital	10	12
Subacute referral to hospital	32	16
Elective referral hospital	50	32
Subacute referral to specialist	18	7
Elective referral to specialist	64	38
Referral to radiology	86	30
Other referral e.g. physiotherapist (primary care services)	20	32
Follow-up in the clinic	165	183
No plan for follow-up	106	198
Change in the intended treatment of the patient		
I will initiate medication	104	107
I will refer for treatment	87	68
I will initiate other treatment	64	115
I will not initiate treatment	283	277
Other	4*	11*

Comparison between complete before and after registrations (N=528)
The questions was designed as multiple choice. Results are provided as the number of registrations.
* Referral for treatment in physiotherapy

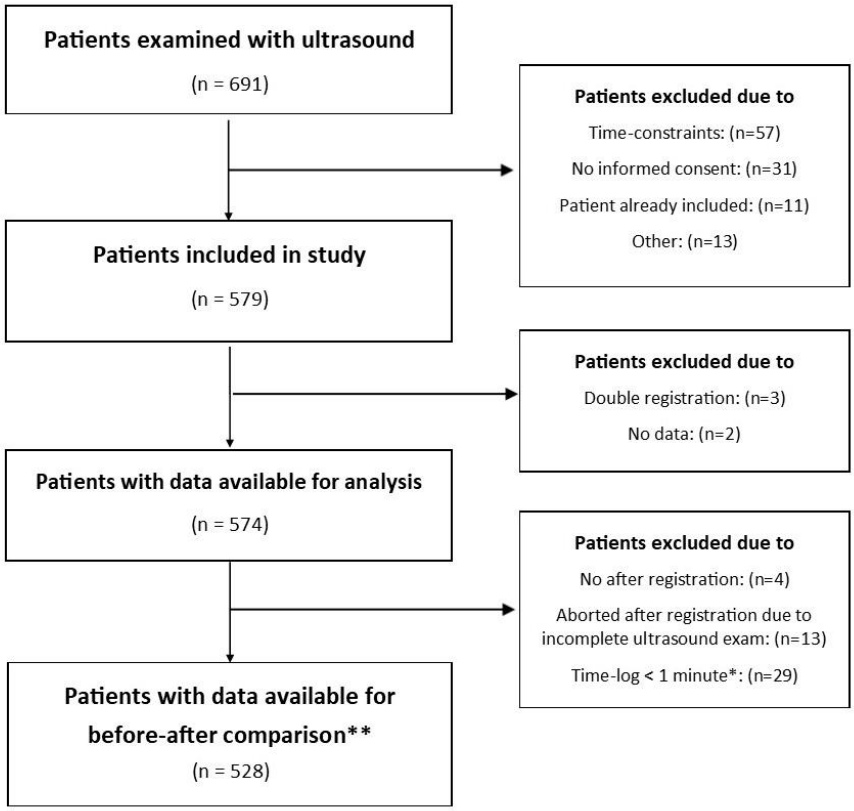
Figure 1.

[Attached in a separate file]
Figure legend: Patient flow diagram

Figure 2.
[Attached in a separate file]
Figure legend: Ultrasound competences of the participating general practitioners

Figure 3.
[Attached in a separate file]
Figure legend: Use of ultrasonography in general practice

Figure 1 Patient flow diagram



* Time-log < 1 minute = No separation between before and after registration in the questionnaire. Before-registration was deleted.

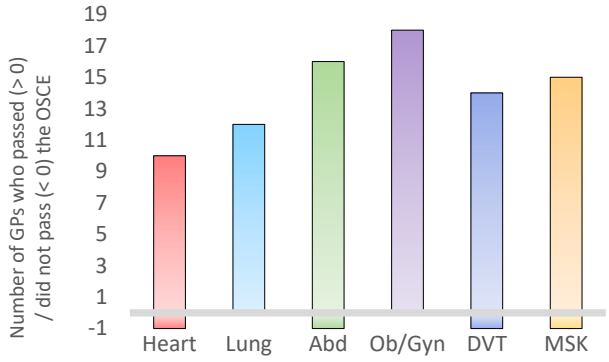
** We had 545 before registrations, 557 after registrations and 528 complete before and after registrations.

Figure 2 Ultrasound competences of the participating general practitioners.

Assessment of ultrasound competences (N=19)*

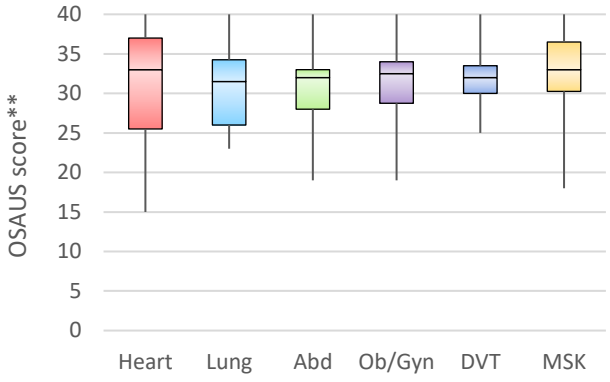
OSCE evaluation

Sixteen GPs (84.2%) passed the OSCE evaluations for all applications.
One GP failed to pass two out of six applications: Heart (incorrect probe placement) and abdomen (wrong measurement of bladder volume)
One GP failed to pass one out of four applications: DVT (unsystematic approach and incorrect placement of probe)
One GP failed to pass one out of two applications: MSK (insufficient knowledge, unsystematic approach and incorrect probe placement).



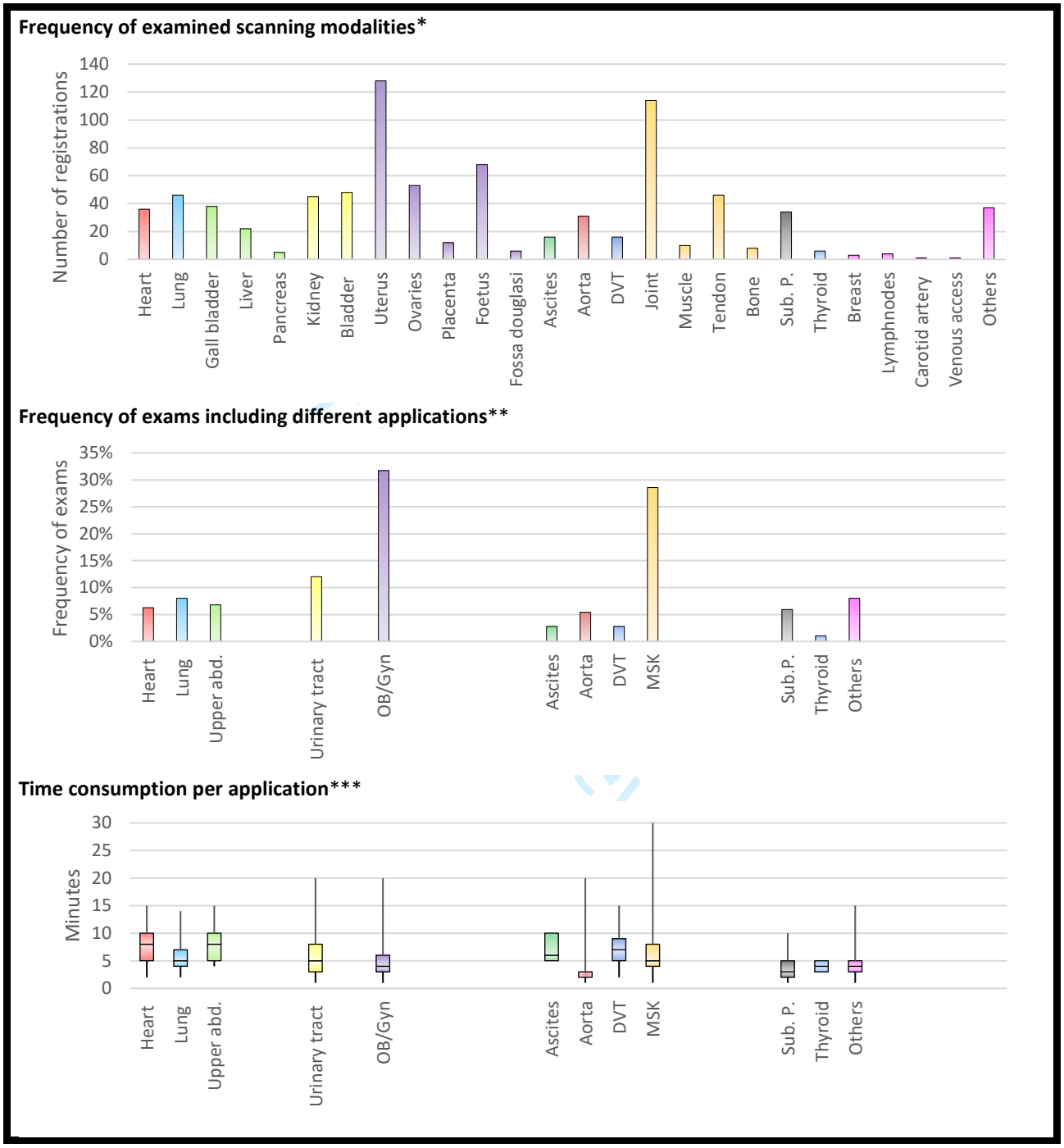
OSAUS evaluation

The average individual OSAUS scores** varied from 18.5 to 40.0 across applications while the OSAUS scores for each application across GPs varies from 15.0 to 40.0.



* A teacher in PoC-US and radiology specialist (OG) assessed 19 of the GPs' performances in a standardised setting using an adapted version of a generic ultrasound rating scale (The Objective Structured Assessment of Ultrasound Skills (OSAUS)[17]) and asked questions about the examination according to an objective structured clinical examination (OSCE) evaluation sheet. The GPs were asked to demonstrate PoC-US according to their usual routine and they were only assessed in the applications that they normally used.
One GPs declined to participate in this evaluation.
** OSAUS: objective structured assessment of ultrasounds skills assessed on a scale from 0-40.
GP= general practitioner, Abd= abdomen, Ob/Gyn= Obstetric and gynaecological, DVT= Deep venous thrombosis, MSK= musculoskeletal

Figure 3 Use of ultrasonography in general practice



* After registrations of scanning modalities (N= 834)

** Number of exams with an after-registration of scanning modalities (N=574). The registered scanning modalities are categorized according to application: Upper abd.= Upper abdominal organs (including liver, gall bladder, pancreas), *Urinary tract* (including kidney, and bladder), *OB/Gyn*= Obstetric and gynaecological (including uterus, ovaries, placenta, foetus, and fossa douglasi), *Ascites*= scans for abdominal flee fluid, *DVT*= Scans for deep venous thrombosis, *MSK*= musculoskeletal (including joints, muscle, tendon, bone, and joint puncture), *Sub.P*= Subcutaneous process, The *others* category includes free text answers and registered applications with a frequency below five examinations: intestines incl. appendix and rectum (N=7), bursa (N=6), unclassified abdominal structures (N=6), testis (N=5), amnion fluid (N=4), lymph nodes (N=4), breast (N=3), soft tissue (N=2), hernia (N=2), ureter (N=1), Larynx (N=1), varicose vein (N=1), unclassified abscess (N=1), carotid artery (N=1), blood vein for venous access (N=1) and unclassified structure on finger (N=1).

*** Time registration if examination only included one application (N=486). Described as median time consumption, interquartile range and range

Appendix 1: Recruitment of participating general practitioners

General practitioners (GPs) were recruited through ultrasound networks, conferences, and teaching sessions. Interested GPs were asked to answer a questionnaire including background information. We included the first 20 GPs, who based on the questionnaire, met the inclusion criteria and not the exclusion criteria.

Between January 2018 and August 2018, 20 general practitioners from 18 general practice clinics were included through the Danish society of ultrasound in general practice (N=10), an ultrasound group on Facebook (N=8), and teaching sessions (N=2).

Questionnaire including background characteristics

Question number	Question	Catagory
BQ 1.1	How old are you?	Age
BQ 1.2	Are you a woman/man?	Gender
BQ 1.3	How many years have you been a GP?	Experience
BQ 1.4	Which year did you graduate as a doctor?	Experience
BQ 1.5	How long have you been using ultrasound?	Experience
BQ 1.6	Would you characterize your practice as a predominantly rural, urban or mixed	Location
BQ 1.7	How is your practice organized? (solo, partnership, collaboration)	Organization
BQ 1.8	How many patients are assigned to your practice?	Organization
BQ 1.9	How many days a week do you do clinical work?	Organization
BQ 2.0	In which region do you practice?	Location
BQ 2.1	What is the approximate distance from your practice to the nearest radiology department where US can be performed?	Location
BQ 2.2	What kind of US device (name, model, year) and probes do you have?	Equipment
BQ 2.3	What kind of ultrasound education/training did you receive?	Experience
BQ 2.4	Which anatomical areas do you scan with ultrasound?	use
BQ 2.5	How often do you use ultrasound?	Frequency
BQ 2.6	Do you have a conflict of interest, participating in this study?	COI

Appendix 2: Evaluation of ultrasound competences

Each participating GP was invited to a one-hour individual meeting 1-16 days prior to the beginning of the data collection. In this meeting, the participating GP was introduced to the data collection tools and the study procedure by the principal investigator. Additionally, each GP participated in individual session where their ultrasound competences were evaluated by a radiologist.

Evaluation procedure

In the evaluation session, GPs were asked to perform ultrasound examinations, as they would normally perform them in their own clinic. GPs were provided with the opportunity to use their own ultrasound device or one of four midrange ultrasound devices: (1) The ACUSON P500 Ultrasound System from Siemens Healthcare (Erlangen, Germany), (2) The Flex Focus 400 from BK Medical Holding Company (Herlev, Denmark), (3) The M-Turbo® ultrasound system from FUJIFILM SonoSite (Bothell, USA) or (4) The LOGIQ P9 from GE Healthcare (Chicago, USA). Ultrasound examinations were performed on healthy volunteers (medical students or a soldier) and a gynecological phantom.

For this study, we used assessment tool developed and used in the certification of general practitioners following an ultrasound course[1]. These assessment tool included evaluation of ultrasound competences within the following applications: Heart (FATE protocol[2]), lung (LUS protocol[3]), Abdominal (including FAST protocol[4] and focused assessment of the gallbladder (Cholecystitis, gallstones), kidneys (hydronefrosis), bladder(residual urine) and aorta(abdominal aortic aneurism)), deep venous thrombosis (2-point-compression protocol[5]), musculoskeletal (focused assessment of joints, tendons and muscles) and gynaecological (location of intrauterine device, Location of intrauterine foetus, detection of foetal heartbeat, head position in third trimester, detection of fluid in fossa douglasi). The participating GPs used a range of different ultrasound applications during their daily clinical work. Some more than others. GPs were only asked to demonstrate ultrasound examinations within applications that they used during their daily clinical work.

The evaluation sessions included assessment of one ultrasound application after another. The participating GPs demonstrated their ultrasound competences by scanning healthy volunteers (and/or a transvaginal ultrasound training phantom) while a radiologist assessed their skills and asked questions about the examination. After each demonstration, the participants were presented with two application-specific clinical cases from general practice including ultrasound videos with pathology. The participants were then asked to interpret the videos and integrate the findings into the context of the case.

Assessment tools

After this scanning sessions the radiologist evaluated the participants' ultrasound competences for each application using a modified version of the generic ultrasound rating scale *The Objective Structured Assessment of Ultrasound Skills* (OSAUS)[6] and an *objective structured clinical examination* (OSCE)[7].

The generic OSAUS evaluation included assessment (rated on a scale: 1-5 points) of the participants': (1) knowledge of the indication for the examination, (2) applied knowledge of ultrasound equipment, (3) performed image optimization), (4) systematic approach while performing the examination, (5) ability to Interpret images, (6) documentation of the examination, and (7) medical decision making. The generic OSAUS score was adapted to a general practice setting by removing assessment of participant's ability to document ultrasound images, as the GPs were unable to document ultrasound images in their

medical record system. Additionally, the generic scale was extended with two clinical cases from general practice to further assess the clinical decision making (rated on a scale: 1-5 points). Hence, the adapted OSAUS score included a scale from 0-40 points.

The OSCE evaluation was designed to evaluate the participants' clinical skill performance. The radiologist gave the participants marks on a mark scheme for each step that they perform correctly. Based on the marks, the radiologist made an overall evaluation of each participant for each applications (passed/not passed).

The evaluation of the participants' ultrasound competences resulted in an individual OSAUS score (0-40 points) and an individual passed/not passed OSCE result for each application. The participating GPs were blinded to the results of this evaluation.

OSAUS evaluation

Application: _____

Indication for the examinations	**1**	**2**	**3**	**4**	**5**
If applicable. Reviewing patient history and knowing why the examination is indicated.	Displays poor knowledge of the indication for the examination		Displays some knowledge of the indication for the examinations		Displays ample knowledge for the examination
Applied knowledge of ultrasound equipment	**1**	**2**	**3**	**4**	**5**
Familiarity with the equipment and its functions i.e. selecting probe, using buttons and application of gel	Unable to operate equipment		Operates the equipment with some experience		Familiar with operating the equipment
Image optimization	**1**	**2**	**3**	**4**	**5**
Consistently ensuring optimal image quality by adjusting gain, depth, focus, frequency etc.	Fails to optimize images		Competent image optimization but not done consistently		Consistent optimization of images
Systematic examination	**1**	**2**	**3**	**4**	**5**
Consistently displaying systematic approach to the examination and presentation of relevant structures according to guidelines	Unsystematic approach		Displays some systematic approach		Consistently displays systematic approach
Interpretation of images	**1**	**2**	**3**	**4**	**5**
Recognition of image patterns and interpretation of findings	Unable to interpret any findings		Does not consistently interpret findings correctly		Consistently interpret findings correctly
Medical decision making	**1**	**2**	**3**	**4**	**5**
Ability to integrate scan results into the care of the patient and medical decision making	Unable to integrate findings into medical decision making		Able to integrate findings into a clinical context		Consistently integrates findings into medical decision making
Case 1	**1**	**2**	**3**	**4**	**5**
Case 2	**1**	**2**	**3**	**4**	**5**

OSCE evaluation of focused ultrasound assessment of the heart (FATE protocol)

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	

Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for Subcostal four chamber image	
Correct placement of transducer for Subcostal inferior vena cava image	
Correct placement of transducer for Apical four chamber image	
Correct placement of transducer for Parasternal long axis image	
Correct placement of transducer for Parasternal short axis image	
Correct placement of transducer for pleura image	
Is able to account for findings in relation to pericardial effusion	
Is able to account for findings in relation to cardiomyopathy	
Is able to account for findings in relation to reduced ejection fraction	
Is able to account for findings in relation to right ventricular stress	
Is able to account for findings in relation to the size of inferior vena cava.	
Is able to demonstrate a systematic approach in the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound assessment of the lung (FLUS-protocol)

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for anterior positions with the patient in the sitting position	
Correct placement of transducer for posterior positions with the patient in the sitting position	
Correct placement of transducer for anterior and lateral positions with the patient laying down	
Correct placement of transducer for posterior positions with the patient laying down	
Is able to account for findings in relation to the diagnosis and exclusion of pneumothorax	
Is able to account for findings in relation to the diagnosis and exclusion of interstitial syndrome	
Is able to account for findings in relation to the diagnosis and exclusion of pleura effusion	
Is able to account for ultrasound findings in patients with Chronic Obstructive Pulmonary Disease (COPD)	
Is familiar with procedure-related lung ultrasound	
Is able to demonstrate a systematic approach in the examination	
Is able to account for the impact of the patient position on the interpretation of the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to give examples of dynamic changes in relation to pathological findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound assessment for deep vein thrombosis

(2-point compression protocol)

	Yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Correct position of patient	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for scanning proximal veins	
Correct placement of transducer for scanning veins in fossa poplitea	
Is able to account for findings that are diagnostic for deep vein thrombosis	
Is able to account for findings that rule-out deep vein thrombosis	
Is able to demonstrate a systematic approach in the examination	
Is able to account for typical locations of a thrombus in relation to deep vein thrombosis	
Is able to account for the importance of the patients position when interpreting images	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
This ultrasound competence is approved	

OSCE evaluation of focused ultrasound of the abdomen

(FAST protocol and focused assessment of Gallbladder, kidneys, aorta, bladder)

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for assessing aorta (detection of abdominal aortic aneurism)	
Correct measure of the abdominal aortic diameter	
Correct placement of transducer for assessning the gall bladder (gallstones and Cholecystitis)	
Correct demonstration of Murphys sign	
Correct measurement of gallbladder wall	
Correct placement of transducer for scanning kidneys and assessing hydronefrosis	
Is able to account for typical locations of hydronefrosis	
Correct placement of transducer for scanning bladder and assessing recidual urine	
Correct measure and calculation of bladder volume	
Correct placement of transducer for detection abdominal free fluid (ascites)	
Is able to account for free fluid in fossa hepatorenale, fossa splenorenale and fossa Douglasi / rectovesciale	

Is able to explain the effect of fasting for the outcome of the examination	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathology on FAS-USS	
This ultrasound competence is approved	

OSCE evaluation of focused pelvic ultrasound

	yes
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer (both endovaginal and abdominal transducer)	
Correct placement of transducer for assessing uterus and ovaries	
Correct selection of transducer and correct placement of transducer for location IUD	
Correct selection of transducer and correct placement of transducer for detecting an intrauterine pregnancy	
Correct selection of transducer and correct placement of transducer for detecting an extra uterine pregnancy	
Correct selection of transducer and correct placement of transducer for detecting a fetal heart beat	
Correct selection of transducer and correct placement of transducer for estimation of gestational age (CRL)	
Correct selection of transducer and correct placement of transducer for detecting abdominal free fluid	
Is able to account for free fluid in fossa hepatorenale, fossa splenorenale and fossa Douglasi / rectovesciale	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathological finding on pelvic ultrasound	
This ultrasound competence is approved	

OSCE evaluation of focused musculoskeletal ultrasound

	JA
Is able to account for indication and possible contraindications for performing the examination	
Adequate patient communication and preparation for the examination	
Setting-up the ultrasound equipment	
Is able to account for the selection of transducer	
Correct placement of transducer for assessing effusion surrounding the long head of the biceps muscle (caput longum biceps bracii)	
Correct placement of transducer for assessing tenosynovitis in the long head of the biceps muscle (caput longum biceps bracii)	
Correct placement of transducer for detection of inflammation in the bursa (bursitis subacromialis)	
Correct placement of transducer for detection of lateral epicondylitis (tennis elbow)	
Correct placement of transducer for assessing fluid accumulation in the knee (The suprapatellar bursa)	
Correct placement of transducer for detection of Patella Tendinopathy (Jumpers knee)	
Correct placement of transducer for assessing ligamentum patellae	
Correct placement of transducer for detection of Osgood-Schlatter	
Correct placement of transducer for detection of Achilles tendinitis	

Correct placement of transducer for detection of Achilles peritendinitis	
Correct placement of transducer for detection of rupture in the Achilles tendon	
Correct placement of transducer for detection of fascia plantaris tendinitis	
Is able to account for important pitfalls and limitations in relation to the examination.	
Is able to account for the consequences following normal ultrasound findings	
Is able to account for the consequences following pathological ultrasound findings	
Is able to provide examples of dynamic changes in relation to pathological finding on musculoskeletal ultrasound	
This ultrasound competence is approved	

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Appendix 3: Before-After Questionnaire

Developing the before-after questionnaire:

The registration tools included a before-after PoC-US questionnaire developed on the basis of an interview study conducted in Danish general practice(16). The questionnaire was pilot tested in consecutive rounds of one-week registrations - first by the authors (CAA and MBJ) and secondly by five GPs. Adaptions followed after each round according to feedback from both GPs and patients.

The before-after questionnaire was developed to avoid missing values. However, missing data occurred when the GP aborted the questionnaire before completing the registration (N=4), when the GP declared that he/she was unable to produce the ultrasound images due to e.g. bowel gas (N=13) or in cases where the time separation between before and after registrations was below one minute. In these cases, we assumed there was no separation between the registrations and the before registration was deleted (N=29).

Questions BEFORE the use of POC-US:

Question number	Question	Possible answers
PQ 1.1	GP ID number	GPxx
PQ 1.2	Patient ID number	Pxxx
PQ 1.3	Date	Dxxxxxxxx
PQ 1.4	Patient gender	Male/female
PQ 1.5	Patient Age	xxx years
Q 1.1	What is the main reason to use POC-US in this patient?	Rule-in/Rule-out Explore
Q 1.2	Which organs/positions do you expect to scan?	Organs on list
Q 1.3	What is the main tentative diagnosis for this patient?	ICPC2 codes
Q 1.4	Are there any other possible tentative diagnoses in this case?	ICPC2 codes
Q 1.5	What is your overall plan for this patient?	Acute admission to hospital Subacute referral to hospital Elective referral hospital Subacute referral to specialist Elective referral to specialist Referral to radiology Other referral e.g. physiotherapist Follow-up in the clinic No plan for follow-up Other
Q 1.6	Which treatment will you initiate at this stage?	Medication I will refer for treatment I will initiate other treatment None Other

Questions AFTER the use of POC-US:

Question number	Question	Possible answers
Q 2.1	How much time did you use on the POC-US examination?	Minutes
Q 2.2	Which organs/positions did you scan?	Organs in drop-down menu
Q 2.3	Were you able to produce ultrasound images of the relevant structures of (inserted text) ?	Yes No – why not?
Q 2.4	What did you find?	Certain positive findings

		Uncertain positive findings Certain negative findings Uncertain negative findings Incidental findings – please specify in free text
Q 2.5	Before POC-US you registered these tentative diagnoses (inserted text) Have your tentative diagnoses changed?	Yes, the diagnoses have changed but the ICPC2 codes are the same Yes, the diagnoses have changed and the ICPC2 codes have also changed No*
Q 2.6	What is the tentative diagnosis for this patient now?	ICPC2 codes
Q 2.7	Are there any other possible tentative diagnoses for this patient (please specify)?	ICPC2 codes
Q 2.8	How is your confidence in your main tentative diagnosis, after you have used POC-US?	Highly increased confidence More confidence unchanged confidence Less confidence Highly reduced confidence.
Q 2.9	Before POC-US you registered this plan (inserted text) for the patient. Has your overall plan changed?	Yes No**
Q 3.0	What is your overall plan for this patient, now?	Acute admission to hospital Subacute referral to hospital Elective referral hospital Subacute referral to specialist Elective referral to specialist Referral to radiology Other referral e.g. physiotherapist Follow-up in the clinic No plan for follow-up Other
Q 3.1	Before POC-US you registered this treatment (inserted text) for the patient. Has your initiated treatment for this patient changed?	Yes No*
Q 3.2	Which treatment will you initiate at this stage?	Medication I will refer for treatment I will initiate other treatment None Other

* Move on to Q2.8

** Move on to Q3.1

Appendix 4: ICPC2 codes registered in the study

Diagnoses registered according to the international classification of primary care 2nd edition (ICPC2)[1].

SYMPTOMS/COMPLAINTS
INFECTIONS
NEOPLASMS
INJURIES
CONGENITAL ANOMALIES
OTHER DIAGNOSES

General and Unspecified A

ICPC2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
A08 Swelling	8				1		
A26 Fear of cancer NOS	1						
A77 Viral disease other/NOS					1		
A79 Malignancy NOS						1	
A85 Adverse effect medical agent		2			1	1	
A94 Perinatal morbidity other		1					
A97 No disease					1		
A98 Health maintenance/prevention	1					1	

Blood, Blood Forming Organs and Immune Mechanism B

ICPC2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
B02 Lymph gland(s) enlarged/painful	5				1		
B27 Fear blood/lymph disease other					1		
B76 Ruptured spleen traumatic	1				1		

Digestive D

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
D01 Abdominal pain/cramps general	7				3		
D02 Abdominal pain epigastric	5	1			3		
D06 Abdominal pain localized other	9	1			3	1	
D07 Dyspepsia/indigestion	2	2			3		
D08 Flatulence/gas/belching	1						
D11 Diarrhoea	1				1		
D12 Constipation	1	1	1		2		
D21 Swallowing problem	1				1		
D23 Hepatomegaly	1						
D24 Abdominal mass	2	1			1		
D25 Abdominal distension	2				2		
D27 Fear of digestive disease other					1		
D73 Gastroenteritis presumed infection		2			1	2	
D75 Malignant neoplasm colon/rectum						1	
D77 Malig. neoplasm digest other						1	1
D78 Neoplasm digest benign/uncertain					1		

D84 Oesophagus disease					1		
D86 Peptic ulcer other					1		
D88 Appendicitis	1	1			1		
D89 Inguinal hernia	1				1		
D91 Abdominal hernia other					1		
D92 Diverticular disease	1	1		1	3	1	
D93 Irritable bowel syndrome					2		
D97 Liver disease NOS		1			1		
D98 Cholecystitis/cholelithiasis	14	5			9	4	
D99 Disease digestive system, other		1					

Cardiovascular K

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
K02 Pressure/tightness of heart	1						
K04 Palpitations/awareness of heart	1						
K06 Prominent veins		1				1	
K07 Swollen ankles/oedema	1				2	1	
K22 Risk factor cardiovascular disease	1				1		
K24 Fear of heart disease	1	1			1	1	
K27 Fear cardiovascular disease other					1		
K28 Limited function/disability (k)	1						
K29 Cardiovascular sympt./complt. other							
K77 Heart failure	9	6			4	2	
K78 Atrial fibrillation/flutter		2				1	
K79 Paroxysmal tachycardia					1		
K84 Heart disease other	5				1	2	
K85 Elevated blood pressure					1		
K86 Hypertension uncomplicated			1		16		1
K87 Hypertension complicated					1		
K92 Atherosclerosis/PVD	4				3		
K93 Pulmonary embolism	1						
K94 Phlebitis/thrombophlebitis	7	3			2		
K95 Varicose veins of leg	2	2			5		
K99 Cardiovascular disease other	17	4			3		

Musculoskeletal L

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
L02 Back symptom/complaint	1	1	1		2	1	
L04 Chest symptom/complaint	3	1			2		
L05 Flank/axilla symptom/complaint	2				1		
L08 Shoulder symptom/complaint	25	2			11	1	
L09 Arm symptom/complaint	3				2		
L10 Elbow symptom/complaint	3				4		
L11 Wrist symptom/complaint	1				1		
L12 Hand/finger symptom/complaint	2				2		
L13 Hip symptom/complaint	5				2		
L14 Leg/thigh symptom/complaint	3	1			3		
L15 Knee symptom/complaint	18	1			11	1	
L16 Ankle symptom/complaint	3				3		
L17 Foot/toe symptom/complaint	6				5		
L18 Muscle pain	2			1	1		
L19 Muscle symptom/complaint NOS	1	3			2	1	
L20 Joint symptom/complaint NOS	4				3	1	
L70 Infections musculoskeletal system		1					

L72 Fracture: radius/ulna	1				1		
L74 Fracture: hand/foot bone		1					
L76 Fracture: other	6				4		
L77 Sprain/strain of ankle		1				1	
L78 Sprain/strain of knee	2	1			4		
L79 Sprain/strain of joint NOS	1	1			2	2	
L80 Dislocation/subluxation				1	1		
L81 Injury musculoskeletal NOS	3	3			5	2	
L84 Back syndrome w/o radiating pain	1				1		
L86 Back syndrome with radiating pain					1		
L87 Bursitis/tendinitis/synovitis NOS	52	11	1		67	7	
L90 Osteoarthrosis of knee	1	2			2	2	
L91 Osteoarthrosis other	3	1			4	1	
L92 Shoulder syndrome	7	5	1		15	4	
L93 Tennis elbow	2				2		
L96 Acute internal damage knee		1				1	
L97 Neoplasm benign/unspec musculo	1				2		
L99 Musculoskeletal disease, other	1		1		1		1

Neurological N

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
N06 Sensation disturbance other		1			1		
N82 (scannede nyre –positivt fund)– evt R82??					1		

Psychological P

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
P01 Feeling anxious/nervous/tense					1		
P02 Acute stress reaction					2		

Respiratory R

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
R01 Pain respiratory system	1				1		
R02 Shortness of breath/dyspnoea	6				8		
R04 Breathing problem	1	1			1	1	
R05 Cough	1				3		
R21 Throat symptom/complaint					3		
R27 Fear of respiratory disease	1				2		
R29 Respiratory symptom/complaint oth	1						
R74 Upper respiratory infection acute		5			1	1	
R78 Acute bronchitis/bronchiolitis		6			1	4	
R80 Influenza		1			1		
R81 Pneumonia	17	1			11		
R82 Pleurisy/pleural effusion	4	2	1		4	1	
R84 Malignant neoplasm bronchus/lung	1				1		
R88 Injury respiratory other		1					
R91 (1. kode pleurit) måske det skulle være R92?		1			1		
R95 Chronic obstructive pulmonary dis		3	1		2	3	
R96 Asthma		2			2		

R99 Respiratory disease other	1			1			

Skin S

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
S04 Lump/swelling localized	5	2			2	1	
S05 Lumps/swellings generalized	1				1		
S10 Boil/carbuncle	4	4			2	2	
S15 Foreign body in skin	2				1		
S16 Bruise/contusion	1	2	1		3	1	1
S18 Laceration/cut					1		
S76 Skin infection other	3	1			8		
S78 Lipoma	2	1	1		5	1	1
S93 Sebaceous cyst					2		
S99 Skin disease, other					1		

Endocrine/Metabolic and Nutritional T

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
T01 Excessive thirst		1				1	
T07 Weight gain		1					
T08 Weight loss	1				1		
T11 Dehydration						1	
T81 Goitre	3	1			2		
T92 Gout	3				2		
T99 Endocrine/metab/nutrit. dis. other	1	2			1	1	

Urological U

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
U01 Dysuria/painful urination	1				1		
U02 Urinary frequency/urgency	1				1		
U04 Incontinence urine	1				1		
U05 Urination problems other	2				2		
U06 Haematuria	2	1					1
U07 Urine symptom/complaint other					1		
U08 Urinary retention	8	2	1		8	2	
U13 Bladder symptom/complaint other	1	1			1		
U14 Kidney symptom/complaint	2						
U70 Pyelonephritis/pyelitis		2					
U71 Cystitis/urinary infection other	5	2	2		11	2	1
U78 Benign neoplasm urinary tract	1				1		
U79 Neoplasm urinary tract NOS					1		
U95 Urinary calculus	6	1			4	3	
U99 Urinary disease, other	5	5	1		2	3	

Pregnancy, Childbearing, Family Planning W

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
W03 Antepartum bleeding	3						
W11 Contraception oral	2				2		
W12 Contraception intrauterine	41	3	1		40	2	1
W15 Infertility/subfertility					1		
W18 Post-partum symptom/complaint oth.					1		
W27 Fear complications of pregnancy	3				1		
W29 Pregnancy symptom/complaint other	2				1		
W30	1				2		
W71 Infection complicating pregnancy		1					1
W72 Malignant neoplasm relate to preg.	1				1		
W78 Pregnancy	58	4			62	1	
W80 Ectopic pregnancy	1	3	1			2	
W82 Abortion spontaneous	4	3			2		
W83 Abortion induced	1				1		
W84 Pregnancy high risk	2	1			3	1	
W96 Complications of puerperium other	1						

Female Genital X

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
X01 Genital pain female	1	1	1			1	1
X05 Menstruation absent/scanty	2				1		
X06 Menstruation excessive	3				2		
X07 Menstruation irregular/frequent	1	1			2	1	
X08 Intermenstrual bleeding	3				1		
X11 Menopausal symptom/complaint	1				1		
X12 Postmenopausal bleeding	2	1			2	1	
X13 Postcoital bleeding	2				1		
X14 Vaginal discharge	1	1				1	
X15 Vaginal symptom/complaint other	1				1		
X17 Pelvis symptom/complaint female	5				4		
X19 Breast lump/mass female	2	1			1		
X25 Fear of genital cancer female	1				1		
X27 Fear genital/breast disease other (f)	1				1		
X28 Limited function/disability (x)					1		
X29 Genital symptom/complt female oth.					1		
X72 Genital candidiasis female					1		
X74 Pelvic inflammatory disease		2					
X77 Malignant neoplasm genital other (f)					2	1	
X78 Fibromyoma uterus		1	1		4	1	
X79 Benign neoplasm breast female		1				1	
X80 Benign neoplasm female genital		1		1	3		
X81 Genital neoplasm oth/unspecied (f)		1					
X84 Vaginitis/vulvitis NOS						1	
X87 Uterovaginal prolapse	1				1	1	
X92 Chlamydia infection genital (f)						1	
X99 Genital disease female, other	4	2			6	1	

Male Genital Y

ICICP2	Before ICPC2 1	Before ICPC2 2	Before ICPC2 3	Before ICPC2 4	After ICPC2 1	After ICPC2 2	After ICPC2 3
Y02 Pain in testis/scrotum	2				1		

Y74 Orchitis/epididymitis					1		
Y82 Hypospadias	1				1		
Y85 Benign prostatic hypertrophy			1	1		1	1

(1) The World Organization of Family Doctors' (WONCA) International Classification Committee (WICC). International Classification of Primary Care. 2015; Available at: https://www.globalfamilydoctor.com/site/DefaultSite/filesystem/documents/Groups/WICC/International%20Classification%20of%20Primary%20Care%20Dec16.pdf. Accessed 14 oct, 2019.

Appendix 5. Changes in registered tentative diagnoses codes before and after ultrasonography

N=528	Registrations before ultrasound Number (%)	Registrations after ultrasound Number (%)	Ultrasound entailed a more specific diagnosis
Number of patients with 1 ICPC2 code	371 (70.3)	436 (82.6)	The number of patients with >1 ICPC2 code was reduced from 29.6% to 17.5%
Number of patients with 2 ICPC2 codes	138 (26.1)	81 (15.3)	
Number of patients with 3 ICPC2 codes	13 (2.5)	11 (2.1)	
Number of patients with 4 ICPC2 codes	6 (1.1)	0 (0.0)	
Symptoms/complaints codes	249 (47.2)	193 (36.6)	The number of patients with symptom codes reduced while the number of patients with disease specific ICPC2 codes increased
Infection codes	33 (6.3)	43 (8.1)	
Neoplasms codes	6 (1.1)	21 (4.0)	
Injuries codes	17 (3.2)	24 (4.5)	
Congenital anomalies codes	1 (0.2)	1 (0.2)	
Other diagnoses codes	221 (41.9)	244 (46.2)	
Wrong code	0 (0.0)	2 (0.4)	

* Wrong code = Registered code in the questionnaire that did not translate into the ICPC2 coding system.
ICPC2= international Classification of primary care 2nd edition [18]

Manuscript according to the Strobe-checklist

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	-
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5 Appendix 2 Appendix 3
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5 Published Statistical analysis plan
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	Appendix 3
		(*d*) If applicable, explain how loss to follow-up was addressed	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1

Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) Summarise follow-up time (eg, average and total amount)	Table 1 Figure 1 -
Outcome data	15*	Report numbers of outcome events or summary measures over time	-
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	6-7 Figure 3 + 4
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.