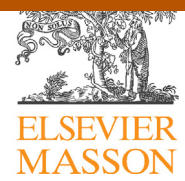
Archives of Cardiovascular Disease (2013) 106, 644—650



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CLINICAL RESEARCH

Reliability of the measurement of the abdominal aortic diameter by novice operators using a pocket-sized ultrasound system

Étude de la fiabilité de la mesure du diamètre de l'aorte abdominale effectuée par des médecins novices avec un échographe de poche, en vue du dépistage des anévrysmes

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Received 30 April 2013; received in revised form 30 July 2013; accepted 29 August 2013
Available online 15 November 2013

KEYWORDS
Abdominal aortic aneurysm;
Screening;

Summary
Background. — Despite favorable results of randomized studies and several guidelines, screening for abdominal aortic aneurysm is poorly implemented in most countries. In order to implement an effective abdominal aortic aneurysm screening programme, training of physicians other than

Abbreviations: AAA, abdominal aortic aneurysm; CI, confidence interval; ICC, intraclass correlation coefficient; NHS, National Health Service.

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1875-2136/$ — see front matter
http://dx.doi.org/10.1016/j.acvd.2013.08.004

Ultrasound;
Experience;
Reliability

cardiovascular imaging specialists is necessary. Also, the use of pocket-sized ultrasound systems seems an appealing alternative to conventional echography machines for large-scale screening.
Aims. — To test the hypothesis that, after a short period of specific training with a pocket-sized ultrasound system, novice operators could reliably measure the abdominal aortic diameter. We assessed the agreement between abdominal aortic diameter measurements from novice operators using a pocket-sized ultrasound system and experts using conventional machines.
Methods. — After focused training of novice operators, the abdominal aortic diameter was independently measured at least four times: by two experts using conventional ultrasound, by one expert using a pocket-sized ultrasound system and by at least one novice operator using the pocket-sized system; each operator was blinded to the others.
Results. — The aortic diameters of 56 patients were measured. The intraclass correlation coefficients between the four sets of measurement were all > 0.91 and the mean difference between the measurements was negligible (<1 mm). The interoperator variability for experts using conventional machines versus novices using pocket-sized machines was ≤ 4 mm in 92.0% of cases. No learning curve over time was noted.
Conclusion. — In order to screen for abdominal aortic aneurysm, the abdominal aortic diameter can be accurately measured by non-specialist physicians with pocket-sized ultrasound devices after a short period of training.

MOTS CLÉS
Anévrysme de l'aorte abdominale ;
Dépistage ;
Échographe de poche ;
Expérience ;
Fiabilité

Résumé
Contexte. — Malgré la publication de résultats favorables et les recommandations émises, le dépistage des anévrysmes de l'aorte abdominale est peu réalisé dans la plupart des pays. Il apparaît donc nécessaire de former d'autres médecins que les spécialistes. La diffusion des échographes de poche semble également bien adaptée à un dépistage à large échelle.
Objectif. — Pour tester l'hypothèse que des médecins novices, après une courte formation ciblée, et avec un échographe de poche, pourraient mesurer le diamètre de l'aorte abdominale de manière fiable. Évaluer l'accord entre les mesures du diamètre de l'aorte abdominale effectuées par des médecins novices utilisant un échographe de poche, et celles réalisées par des experts utilisant un échographe classique.
Méthodes. — Après une courte formation ciblée des novices, le diamètre de l'aorte abdominale de chaque patient a été mesuré de manière indépendante à au moins quatre reprises, en insu des autres mesures réalisées : deux fois par des experts avec l'échographe classique, une fois par un expert utilisant l'échographe de poche et au moins une fois par un novice avec le même échographe de poche.
Résultats. — Les diamètres aortiques de 56 patients ont été mesurés. Le coefficient de corrélation intra-classe entre les quatre mesures était > 0,91 et la moyenne des différences des mesures était négligeable (< 1 mm) ; la variabilité inter-observateur était ≤ 4 mm dans 92 % des cas ; et il n'y a pas de courbe d'apprentissage de la mesure avec le temps.
Conclusions. — Le diamètre de l'aorte abdominale peut être mesuré de manière valide par des médecins inexpérimentés, après une courte formation, à l'aide d'un échographe de poche. Ceux-ci peuvent acquérir rapidement des performances très acceptables, et être aptes à la réalisation du dépistage d'anévrysme de l'aorte abdominale.

Introduction

Abdominal aortic aneurysm (AAA) is conventionally defined as an aortic diameter enlarged by at least 50%. The main risk of AAA is rupture, with associated high mortality [1]. This risk of rupture increases with AAA diameter. AAA-related mortality can be reduced by ultrasound screening of individuals at risk, with prompt intervention for the larger lesions (>50—55 mm), as is recommended in several countries [2]. The simplest recommendations have been published in the UK, where all men aged > 65 years should be screened [3]. In France, a recent national guideline document recommends AAA screening in men aged 65—75 years with a history of smoking or aged 55—75 years if they have a family history of AAA [4]. The application of such recommendations implies great availability of cardiovascular ultrasound specialists. Some countries (e.g. UK and USA) have opted for large-scale screening, with some difficulties in implementation [5], while in others, including France, population screening has not yet been implemented. To improve screening implementation in our country, it is necessary to train other physicians to carry out the measurement of abdominal aortic diameter, so that they can screen their patients at risk of AAA. Moreover, such a strategy would require the use of handheld ultrasound devices which, due to their small size, high

mobility and low cost, are more suitable for large-scale screening.

We hypothesized that, after a short period of focused training, novice operators using a pocket-sized ultrasound device would be able to reliably measure the abdominal aortic diameter. The aim of this study was to assess the agreement between abdominal aortic diameter measurements performed by novice operators using pocket-sized ultrasound systems and those obtained by experts using conventional ultrasound.

Methods

This prospective study assessed the agreement of measurements taken in a teaching hospital between May and July 2012 in two successive phases, according to level of expertise (novice versus expert) and type of ultrasound machine (pocket-sized versus conventional).

In the first phase, novice operators (medical students) were instructed during three 3-hour training sessions in the use of a pocket-sized ultrasound system (Vscan®; GE Healthcare, Wauwatosa, WI, USA) to measure the abdominal aortic diameter, with a phased-array probe 1.7—3.8 MHz. Initially, we set a theoretical and practical training programme for ultrasound imaging of the abdominal aorta. Two hands-on sessions were then organized to learn the settings and manipulation of the pocket-sized ultrasound system, to identify the aorta and its adjacent structures in different tomographical planes and to measure the abdominal aortic diameter.

In the second phase, we compared the measurements performed by novice operators with those obtained by experts, using either the pocket-sized system or a conventional ultrasound machine (iE33; Philips Healthcare, Boston, MA, USA). For this machine, we used a 5 MHz phased-array probe. Each operator used only one of the two ultrasound devices on each patient and averaged the results of three measurements of the external anteroposterior diameter of the infrarenal aorta in the transverse view, immediately above its bifurcation. In case of AAA (defined as a diameter > 30 mm), the maximal external anteroposterior diameter was required. Each operator was blinded to the results of the other operators. For each patient, at least four sets of measurements were performed: by two experts using the conventional system, by one expert using the pocket-sized machine and by at least one novice operator using the pocket-sized machine. For each patient, the experts involved were randomly selected from the team of nine physicians in our laboratory. Measurements by two experts using a conventional machine, one expert using the pocket-sized machine and at least one novice using the pocket-sized machine were each compared with each other (Fig. 1).

All patients included in this study were initially hospitalized for cardiovascular diseases other than aortic disease and were invited to take part into this study. Patients who had previously undergone operations on the abdominal aorta and those with an unstable haemodynamic state or any other condition jeopardizing their immediate prognosis were excluded from the study. Patients who declined our invitation to participate in the study were excluded and refusals were reported. Informed consent was obtained from all

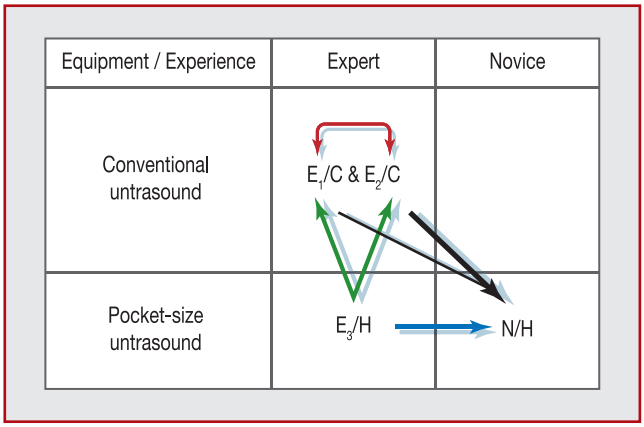

Figure 1. Interoperator comparisons of aorta measurements according to expertise and device. Agreement between experts with conventional ultrasound (red arrow), experts with conventional ultrasound and expert with pocket-sized ultrasound (green arrows), expert with pocket-sized ultrasound and novice with pocket-sized ultrasound (blue arrow), experts with conventional ultrasound and novice with pocket-sized ultrasound (black arrows). C: conventional ultrasound; $E_{1,2,3}$: experts numbers 1, 2, 3; H: handheld ultrasound; N: novice.

participants. The study was approved by the ethical committee of our institution (Committee for Persons Protection, Southwestern France-IV) on 12th April 2012.

Based on the literature [6—12], we took a difference of $\leq$ 4 mm between two measurements of the abdominal aortic diameter to represent good interoperator agreement. We also assessed this reproducibility with more stringent thresholds of $\leq$ 3 mm and $\leq$ 2 mm. For an expected intraclass correlation coefficient (ICC) of 0.80 (i.e. good agreement) with a precision of 0.10 (95% confidence interval [CI] 0.70—0.90), the number of evaluable patients needed for this study was 51. To account for non-evaluable cases, estimated at 15%, a total of 60 patients was necessary.

Qualitative variables are presented as frequencies and percentages; quantitative variables as means $\pm$ standard deviations. To assess the agreements, ICCs were calculated using the Shrout-Fleiss method [13] (using the first-case ICC where operators were selected at random for each subject). This coefficient varies between 0 and 1. The ICC reflects a good agreement between the measurements when it is 0.71—0.90 and a very good one when it is $\geq$ 0.91. It is presented with its 95% CIs according to Smith's method [14].

Bland-Altman plots were also plotted for each pair of measurements. These plots represent the differences between two measurements as a function of the mean of the two measurements. The limits of agreement for each plot are also presented to illustrate the fact that we would expect most of the differences between the two measurements to lie between this interval. The statistical analyses were performed with SAS 9.3 software (SAS Institute, Cary, NC, USA).

Results

Overall, 62 patients were recruited. Six patients were excluded because they did not undergo four sets of

Table 1 Abdominal aorta measurements (mm).

Operator/machine	Measurement (mm)
Expert 1/conventional	18.9 ± 5.8
Expert 2/conventional	19.0 ± 6.0
Expert 3/pocket-sized	19.0 ± 5.8
Novice/pocket-sized	18.2 ± 5.8

Data are mean ± standard deviation.

measurements during their hospitalization. Therefore, 56 patients (42 men and 14 women) were included in the analysis. The patients were hospitalized for peripheral artery disease ($n = 30$), coronary bypass surgery ($n = 24$) and cerebrovascular disease ($n = 2$).

Table 1 displays the results of the abdominal aorta measurements. The estimation of the ICC showed good or very good agreement between the pairs of measurements without any statistical difference according to the level of expertise and type of ultrasound machine used (Table 2). Accordingly, the Bland-Altman plots show good concordance between pairs of measurements (Fig. 2), although some measurement differences are outside the ± 4 mm limits of agreement; these correspond to patients who were overweight and therefore had poorer imaging quality. Overall, the mean differences were small: 0.1 mm for expert/conventional versus expert/conventional (Fig. 2A); 0 mm for experts/conventional versus expert/pocket-sized (Fig. 2B); 0.1 mm for expert/pocket-sized versus novice/pocket-sized (Fig. 2C); and 0.7 mm for experts/conventional versus novice/pocket-sized (Fig. 2D), which is not clinically relevant.

Table 3 displays the rates of pairs of measurements with differences ≤ 4 mm, ≤ 3 mm and ≤ 2 mm.

We found no improvement in interoperator agreement between experts/conventional and novice/pocket-sized when we compared the results from the first 28 patients and the second 28 patients, as the 95% CIs of the ICCs overlapped (Table 4).

Discussion

This study confirms the hypothesis that novice vascular ultrasound operators are able to reliably measure the abdominal aortic diameter using a pocket-sized ultrasound system after a short period of focused training.

Population screening for AAA has been validated in elderly men following favorable results in four trials identified in a recent meta-analysis [15]. After 10 years of follow-up, AAA screening by ultrasonography reduced AAA-related mortality by 45%, with a small benefit for total mortality reduction of 2% [15].

These data support the necessity for an organized population screening policy for AAA in elderly men. In the UK, the National Health Service (NHS) launched a campaign in March 2009 for AAA screening (the ''NHS Abdominal Aortic Aneurysm Screening Programme''), which has now been implemented across England [3]. In line with the NHS recommendations, screening is performed by technicians (physicians and non-physicians) who have received theoretical and practical training and rigorous evaluation of ability in men aged ≥ 65 years. In the USA, following the US Preventive Services Task Force guidelines, all male Medicare beneficiaries are invited at the age of 65 years to have an abdominal echography [16]. However, a recent assessment of this screening programme reported that < 10% of potential beneficiaries actually underwent an abdominal echography [5]. In France, no similar screening programmes are implemented currently.

An alternative solution could be the opportunistic screening for AAA when at-risk patients attend a medical facility for any care. Indeed, in a series of 104 ruptured AAA patients managed in Glasgow, 77% were unaware of having an AAA and 76% had been reviewed during the preceding 5 years for diverse medical reasons, but the opportunity to screen for AAA was missed [17]. Such opportunistic screening implies a great availability of specialists in cardiovascular imaging and dedicated ultrasound machines, both of which are beyond current possibilities. Alternatively, non-specialist physicians or technicians could be trained to perform the screening.

In Norway, Singh et al. [18] studied the interoperator variability in the measurement of the maximal abdominal aortic diameter in 112 patients, performed with a conventional ultrasound machine by an expert (radiologist) and three novice operators (nurse, nurse student and radiology technologist) who received theoretical and practical training. In line with our results, the authors reported that the interoperator difference was < 4 mm in 96% of measurements. Moreover, such a screening strategy would require the use of lightweight and low-cost ultrasound devices. Vourvouri et al. [19] studied 101 patients who had two measurements of their aorta taken by two different expert cardiologists, one with a conventional ultrasound and one with an pocket-sized ultrasound system. The agreement between the two methods was found to be 98% with a kappa coefficient of 0.88. Andersen et al. [20] reported a perfect coefficient correlation of 1 between abdominal aortic measurements performed by a cardiologist with a conventional ultrasound and a second using the Vscan® pocket-sized ultrasound

Table 2 Intraclass correlation coefficients for the measurement of abdominal aortic diameter.

Operator/machine	Expert 1/conventional	Expert 2/conventional	Expert 3/pocket-sized
Expert 2/conventional	0.96 (0.94–0.98)	–	–
Expert 3/pocket-sized	0.93 (0.89–0.96)	0.94 (0.90–0.97)	–
Novice/pocket-sized	0.90 (0.84–0.94)	0.92 (0.87–0.95)	0.92 (0.86–0.95)

Data are intraclass correlation coefficient (95% confidence interval).

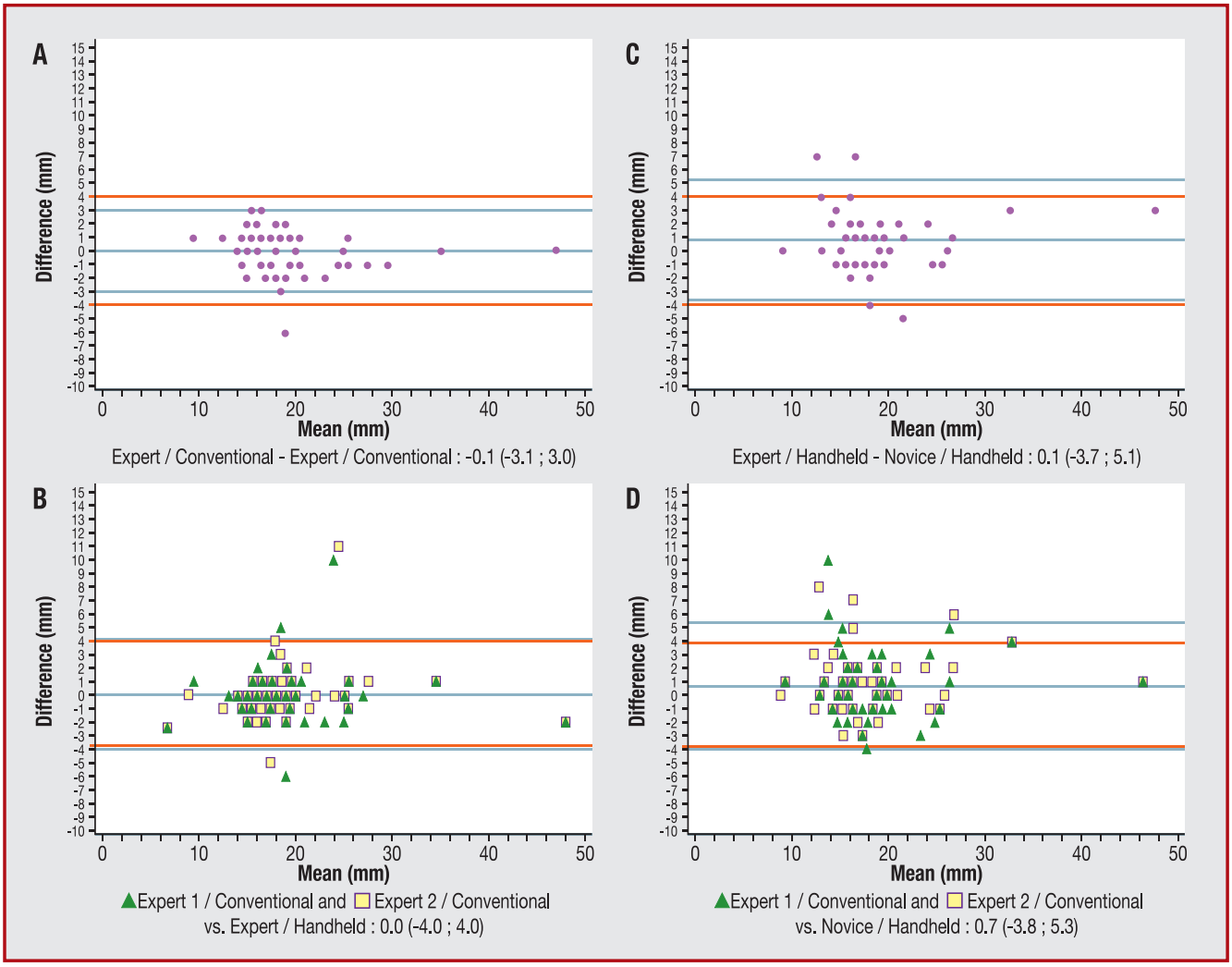

Figure 2. Assessment of the concordance of pairs of measurement of the abdominal aortic diameters according to the Bland-Altman method. Concordance between: (A) expert/conventional machine versus expert/conventional machine; (B) experts/conventional machine versus expert/pocket-sized device; (C) expert/pocket-sized device versus novice/pocket-sized device; and (D) experts/conventional machine versus novice/pocket-sized device.

Table 3 Rates of pairs of measurements within ± 4 mm, ± 3 mm and ± 2 mm.

Operator 1	Operator 2	Pairs of measurements with difference		
		≤4 mm	≤3 mm	≤2 mm
Expert/conventional	Expert/conventional	98.2	98.2	92.9
Expert/conventional	Expert/pocket-sized	95.5	95.5	93.8
Expert/pocket-sized	Novice/pocket-sized	92.9	87.5	83.9
Expert/conventional	Novice/pocket-sized	92.0	88.4	79.5

Data are %.

system. Similarly, Dijos et al. [21] reported a correlation coefficient of 0.98 between two sets of measurements performed by two different cardiologists using the Vscan® machine. However, the correlation coefficient is not appropriate for evaluating interoperator variability and reproducibility. In all of these studies, either the level of expertise or the use of pocket-sized versus conventional devices was assessed. To the best of our knowledge, our study is the first to assess both aspects together in order to propose a radical shift in the current mode of AAA screening in our country, from experts using a conventional machine to trained non-specialists using a pocket-sized ultrasound system.

In our study, medical students without previous ultrasound experience underwent a 9-hour theoretical teaching

Table 4 Assessment of improvement in reproducibility in novice operators: comparison of intraclass correlation coefficients from the first 28 patients and the second 28 patients.

Comparator	Novice/pocket-sized	
	Patients 1—28	Patients 29—56
Expert 1/conventional	0.91 (0.82—0.96)	0.88 (0.76—0.94)
Expert 2/conventional	0.94 (0.88—0.97)	0.89 (0.79—0.95)

Data are intraclass correlation coefficient (95% confidence interval).

and practical hands-on training programme. As we found no learning curve, our study shows that a short period of focused training is sufficient for AAA screening. In this study, the novice operators were medical students, but we foresee no selective bias, so other healthcare professionals could be similarly trained. One important point is that the inexperienced operators should also qualify the imaging quality and refer to a specialist when the imaging quality is poor, as was observed in four of our obese patients.

Our study has some limitations. First, the students who took part in the study were very motivated and we cannot exclude poorer results with less enthusiastic trainees. Also, only two patients had AAA in our study. Accordingly, a larger multicentre study is necessary to assess more patients with a wider range of aortic diameters to ascertain the diagnostic accuracy of such a screening strategy. However, considering that a large proportion of differences in diameter measurements were ≤ 4 mm, large AAAs at high risk of rupture should not be missed. A safe approach would be to require an expert whenever the abdominal aortic diameter exceeds 26 mm, in order not to miss small AAAs (≥ 30 mm), which require further follow-up.

Conclusion

In this study, we have shown that novice operators can accurately measure the abdominal aortic diameter using a pocket-sized ultrasound system after a short period of focused training. Accordingly, the ultrasound screening of AAA by non-specialists appears feasible. Further studies are needed to determine the feasibility of opportunistic AAA screening strategies by non-specialist operators in medical facilities in areas where a systematic screening programme is not implemented.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgements

We are very thankful to Evan Appourchaux, Marie-Claire Bachet, Quentin Ceyrat, Anne-Charlotte Robinson, Kevin Sanchis and Quentin Vincent for their participation in this study and to Marie-Bernadette Houlès, Thierry Kowalski and Christelle Reignez. We are also indebted to Sandrine Baritaud, Sophie Pénichon and Béatrice Vignaud for their technical assistance.

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