Validation of a new bedside echoscopic heart examination resulting in an improvement in echo-lab workflow

Patricia Réant, Marina Dijos, Florence Arsac, Aude Mignot, Fabienne Cadenaule, Annette Aumiaux, Christine Jimenez, Marilyne Dufau, Alain Prévost, Xavier Pillois, Patrick Fort, Raymond Roudaut, Stéphane Lafitte

a Service de cardiologie et d’échocardiographie, hôpital cardiologique Haut-Lévêque, avenue de Magellan, 33605 Pessac, France
b Centre hospitalier universitaire de Bordeaux, université de Bordeaux, Bordeaux, France

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Summary
Background. — In daily cardiology practice, porters are usually required to transfer inpatients who need an echocardiogram to the echocardiographic department (echo-lab).

Aims. — To assess echo-lab personnel workflow and patient transfer delay by comparing the use of a new, ultraportable, echoscopic, pocket-sized device at the bedside with patient transfer to the echo-lab for conventional transthoracic echocardiography, in patients needing pericardial control after cardiac invasive procedures.

Methods. — After validation of echoscopic capabilities for pericardial effusion, left ventricular function and mitral regurgitation grade compared with conventional echocardiography,
we evaluated echo-lab personnel workflow and time to perform bedside echoscopy for pericardial control evaluation after invasive cardiac procedures. This strategy was compared with conventional evaluation at the echo-lab, in terms of personnel workflow, and patients’ transfer, waiting and examination times.

Results. — Concordance between echoscopy and conventional echocardiography for evaluation of pericardial effusion was good (0.97; kappa value 0.86). For left ventricular systolic function and mitral regurgitation evaluations, concordances were 0.96 (kappa value 0.90) and 0.96 (kappa value 0.86), respectively. In the second part of the study, the mean total time required in the bedside echoscopy group was 20.3 ± 5.4 mins vs. 66.0 ± 16.4 mins in the conventional echo-lab group (p < 0.001). The echo-lab strategy needed porters in 100% of cases; 69% of patients needed a wheelchair.

Conclusion. — The use of miniaturized echoscopic tools for pericardial control after invasive cardiac procedures was feasible and accurate, allowing improvement in echo-lab workflow and avoiding patient waiting time and transfer.

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Introduction

Organization of echocardiographic departments (echo-labs) in cardiological institutions has become a real problem due to the dramatic reduction in human resources while demand continues to increase. Porters are usually required to transfer inpatients who need an echocardiogram to the echo-lab, particularly after invasive cardiac or surgical procedures. This is a major cause of patient discomfort and is time consuming in terms of human resources [1] for what is a limited, targeted echocardiographic evaluation that is principally focused on the pericardium and left ventricular (LV) function in such patients.

Due to improvements in electronic technology, portable equipment has been developed for the past 10 years [2—7]. However, these devices have a variety of limitations (insufficient image quality, size and width or battery autonomy) and are difficult to implement in the echo-lab workflow. An important effort has been made recently to miniaturize ultrasounds systems, which has yielded a generation of genuinely pocket-sized ultrasound devices that have grayscale imaging and colour Doppler capabilities (Figs. 1 and 2). As a result of this ultimate portability without degradation of image quality, the performance of echoscopic evaluation directly at the patient’s bedside appears to be feasible for limited diagnostic issues.

We hypothesized that integration of an echoscopic approach in an echo-lab with delocalized evaluation at the bedside would improve workflow and reduce inpatient discomfort without a loss of quality in terms of medical diagnosis. Therefore, we designed this study with two aims: first, to verify that echoscopic evaluation of targeted endpoints such as pericardial effusion, mitral regurgitation (MR) grade and LV function was similar to that obtained with...
Methods

The two parts of this study took place at the University Cardiology Hospital of Bordeaux-Pessac, which has 350 rooms spread over six floors. The echo-lab, cardiology departments, coronary and intensive care units and cardiothoracic surgery department are located on different floors of the same hospital building. In the echo-lab, 15,000 transthoracic echocardiography (TTE) examinations are performed per year. All the examinations done by students or certified sonographers are reviewed by cardiologists with a high level of competence in TTE, using commercially available software for image reviewing and reporting (ComPACS; MediMatic S.R.L., Genoa, Italy). The standard report and images are stored on the hospital’s Picture Archiving and Communication System (PACS) network. This study was approved by our university’s ethics committee.

Validation of echoscopy capabilities compared with conventional echocardiography

One hundred unselected patients referred to the Bordeaux Cardiology Hospital’s echo-lab for conventional indications were enrolled in the first step of this prospective study, to validate the use of the compact echoscopic device vs. conventional TTE performed at the echo-lab. There were no particular exclusion criteria. All patients underwent two ultrasonic examinations: the first was a standard echocardiographic examination performed by an expert physician; this was followed by another cardiac evaluation using a pocket-sized ultrasound device (VSCAN, General Electric Inc., Milwaukee, WI, USA), performed and interpreted by a blinded expert physician. All patients were informed and completed a consent form prior to participation.

For the standard TTE examination, commercially available, top-of-the-line, full-feature echocardiographic systems were used, including Sequoia 512 (Siemens Medical Solutions, Mountainview, CA, USA), IE33 (Philips Medical Systems, Boston, MA, USA), and Vivid 7 (GE Medical Systems, Milwaukee, WI, USA). Next, an evaluation was done using the ultraportable instrument by a physician experienced with TTE and blinded to the results of the standard examination. Each physician completed a summary report that included the following evaluation criteria: semi-quantitative LV systolic function, MR severity and pericardial effusion. Judgment criteria were: ultrasound window quality, good/average/insufficient; LV function, normal/moderate dysfunction/severe dysfunction; mitral regurgitation, absent/mild/moderate/severe; pericardium, normal/slight effusion/moderate effusion/severe effusion.

Comparison of bedside echoscopic evaluation with conventional echo-lab echocardiography

We enrolled 91 consecutive patients who headed to the echo-lab after cardiac invasive procedures such as coronary artery bypass graft (CABG) or radiofrequency catheter ablation (RFCA), or pericardial drainage for pericardial control. Over 6 weeks, 59 patients were included in the bedside echoscopic evaluation group. Then, over the next 3 weeks, 32 patients were included in the conventional TTE group. We
excluded patients with prosthetic valve surgery or plasty associated with CABG (needing Doppler analysis). Demographic and clinical characteristics of the study population and reasons for the cardiac echo evaluation were systematically collected.

The mean judgment criterion was time spent by the sonographer for echoscopic evaluation compared with transferring inpatients to the echo-lab for conventional TTE evaluation. In addition, the mode of transfer and the need for additional personnel (such as porters) or oxygen therapy were noted.

For the bedside echoscopy group, we collected the sonographer’s travel time between the echo-lab and the hospital ward (return trip) for each patient, the duration of the examination conducted by the sonographer and the time required for the referring physician to control and write the report. For the conventional echo-lab group, we registered the need for a porter to transfer the patients to the echo-lab (with or without a wheelchair), the duration of transfer (from admission department to the echo-lab plus travel time from the echo-lab to the patient’s ward; return trip), the time spent by the patient in the waiting room, the duration of the examination and the time required for the referring physician to control and write the report. The main objective was to compare the sonographer’s travel time in the bedside group with the transfer time plus waiting time for patients in the echo-lab group. Each sonographer systematically filled out the same summary report as described for the first part of the study.

The conventional TTE examination performed in the echo-lab was done using a high-end ultrasound scanner (Siemens Medical Solutions, Mountainview, CA, USA) or Vivid S6 (General Electric Medical Systems, Horten, Norway). All patients were informed verbally and filled out a consent form. All echocardiograms were performed by certified sonographers (L.D.M. and R.C.) [8].

The ultraportable ultrasound device

VSCAN (General Electric Medical Systems, Milwaukee, WI, USA) is a pocket-sized ultrasound device with a unit size of 135 × 73 × 28 mm and a transducer size of 120 × 33 × 26 mm. (Figs. 1 and 2) The VSCAN weighs around 390 g and its display measures 3.5 inches, with a resolution of 240 × 320 pixels. The entire unit, including transducer, can fit into the pocket of a laboratory coat along with a small tube of gel. It provides a black-and-white mode for displaying anatomy in real time and a colour-coded overlay for real-time blood flow imaging. The broad-bandwidth phased array probe ranges from 1.7 to 3.8 MHz. The device includes electronic callipers capable of linear measurements. There is an auto-optimize function that automatically adjusts gain function for all depths. Recordings were obtained in standard parasternal, apical and subcostal views, in black-and-white and colour Doppler mode. All images were recorded on the system memory card for later review.

Statistical analysis

Statistical analysis was carried out with the StatEl® version 2 software (AdScience, Paris, France). Concordances between non-parametric data were assessed by Cohen’s kappa test. Concordance was deemed good when the kappa coefficient was between 0.6 and 0.8, and excellent when it exceeded 0.8. Continuous values were expressed as means ± standard deviations. Comparisons between two groups for parametric data were made using the t test. Comparisons between two groups for qualitative data were made using the chi-square test or Fisher’s test for small samples. Differences were considered significant at p < 0.05.

Results

Validation of echoscopy capabilities compared with conventional echocardiography

One hundred patients were enrolled. Indications for echocardiography were: dilated cardiomyopathy in 10% of patients; ischaemic heart disease in 19%; hypertension in 5%; aortic valve stenosis in 9%; MR in 3%; post-cardiac surgery in 12%; pericarditis in 2%; and cardiac transplantation in 7%. Other indications were dyspnoea or chest pain, and specific investigations for diabetic patients.

Using conventional equipment, image quality was ranked as good in 72% of patients, correct in 23% and poor in 5%. In contrast, only 63% of echoscopic images had a good quality rating, whereas only four cases were judged as having poor window quality. Concordance for global window quality criteria was 0.92, with a kappa value of 0.71.

Pericardial effusion was absent in 82% of cases, slight in 14%, moderate in 4% and severe in 0%. Concordance between echoscopy and conventional echocardiography for evaluation of pericardial effusion was good (0.97, with a kappa value of 0.86).

In terms of LV function, 68% patients presented with normal LV function, 17% with moderate dysfunction and 15% with severe LV dysfunction, with TTE. This was similar to the results obtained with the VSCAN (71%, 16% and 13%, respectively). For LV systolic function and MR evaluations, concordances were 0.96 (kappa value 0.90) and 0.96 (kappa value 0.86), respectively.

Bedside evaluation compared with conventional echocardiography at the echo-lab

Ninety-one patients were enrolled (n=59 in the bedside echoscopic group, n=32 in the conventional echo-lab group). Table 1 shows their demographic and clinical characteristics and how they were transported to the echo-lab. There was no significant difference between the two groups concerning age, sex and weight.

Using conventional echo-lab equipment, image quality was ranked as good in 75% of patients, correct in 19% and poor in 6%. Using VSCAN echoscopy, image quality was classified as good in 72% of cases, correct in 22% and poor in 6%.

In the bedside echoscopy group, pericardial effusion was present in 22% of patients (10 patients had slight pericardial effusion; three patients had moderate pericardial effusion). Regarding LV systolic function, 94% of
patients had normal or preserved LV systolic function, 3% had moderate dysfunction and 3% had severe LV dysfunction. Considering MR severity, 8.4% of patients presented with slight MR, 5% with moderate MR and none had severe MR.

In the echo-lab group, pericardial effusion was present in 41% of patients (seven patients had slight pericardial effusion; four patients had moderate pericardial effusion; two patients had severe pericardial effusion). Regarding LV systolic function, 91% patients had normal or preserved LV systolic function and 9% had moderate dysfunction. Considering MR severity, 34% of patients presented with slight MR, 6% with moderate MR and none had severe MR.

Table 2 shows the different time delays with these two strategies. The total time required to evaluate a patient in the bedside group was 20.3 ± 5.4 mins (95% confidence interval [CI] 18.9–21.7 mins) compared with 66.0 ± 16.4 mins (95% CI 59.1–72.9 mins) in the echo-lab group (p < 0.001).

In the bedside echoscopic group, the return journey to the bedside for echoscopy took the sonographer 6.8 ± 3.6 mins per patient (95% CI 5.9–7.7 mins), while the examination duration was 7.0 ± 3.3 mins (95% CI 6.2–7.8 mins) and the time needed by the referent physician to control and write the report was 6.4 ± 2.2 mins (95% CI 5.8–7.0 mins). With this strategy, porters were not necessary.

In the conventional echo-lab group, carrying patients to the echo-lab and back to their cardiology department at the end of the examination took 18.5 ± 7.2 mins (95% CI 15.5–21.5 mins). Patients stayed in the waiting room for 23.0 ± 14.5 mins (95% CI 17.0–29.0 mins), the echocardiographic study lasted for 18.5 ± 7.2 mins (95% CI 15.5–21.5 mins) and the time needed by the referent physician to control and write the report was 6.8 ± 1.2 mins (95% CI 6.3–7.3 mins). Moreover, 100% of patients required porters, 69% were carried in a wheelchair and 9% needed oxygen therapy.

### Discussion

After demonstrating good concordance between the use of the smallest ultrasound echoscopic device and high-end echographic machines for simple diagnoses such as semi-quantitation of pericardial effusion, LV systolic function and MR, this prospective study showed that echoscopic assessment performed at the bedside by certified sonographers after CABG, RFCA or pericardial drainage, can avoid the

| Table 2 Time delays in the two strategies: bedside echoscopy vs echo-lab conventional evaluation. |
|-----------------------------------------------------|-----------------------------------------------------|
| Time (minutes) | Bedside echoscopic group (n = 59) | Conventional echo-lab group (n = 32) | p |
| Patient transfer time | – | 18.1 ± 6.7 |
| Patient waiting time in echo-lab | – | 23.0 ± 14.5 |
| Patient transfer + waiting time | – | 41.1 ± 18.10 | < 0.001 |
| Sonographer travel time | 6.8 ± 3.6 | – |
| Examination duration | 7.0 ± 3.3 | 18.5 ± 7.2 | < 0.001 |
| Referent physician control + report time | 6.4 ± 2.2 | 6.8 ± 1.2 | 0.41 |
| Total delay | 20.3 ± 5.4 | 66.0 ± 16.4 | < 0.001 |

Values are means ± standard deviations.
necessity of porters (in 100% of cases) and waiting and transfer times for patients needing pericardial control after cardiac invasive procedures, compared with conventional evaluation at the echo-lab.

Diagnostic capabilities of portable echocardiography and echoscopy

The capability of portable TTE to diagnose asymptomatic LV dysfunction [9,10], abdominal aorta aneurysms not detected by clinical examination [10], or central venous pressure levels by respiratory dynamics of the inferior vena cava [9], has been demonstrated. The VSCAN is the smallest ever ultrasound device. In the first step of this study (validation), we observed excellent correlations between the echoscopic device and standard TTE for the semiquantitative evaluation of LV function, MR and pericardial effusion.

Improvement in echo-lab workflow and reduction in patient transfers by bedside echo evaluation

Previously, Badano et al. have shown, using the Vivid I portable machine (GE), that the use of digital echocardiography, certified sonographers and a miniaturized echo system improved the cost-effectiveness of the service provided by the echo-lab for inpatients, and avoided patient discomfort arising from prolonged waiting times before and after the examination [11]. Ultraportable TTE with VSCAN may be easier to use than conventional echo machines or the portable devices available during the hospitalization of inpatients. Our results confirmed that the use of certified sonographers and miniaturized echo systems improved workflow in the echo-lab (removing the need for porters in 100% of patients) and avoided patient transfer and prolonged waiting times before and after the examination. This waiting time is expected to be particularly painful for frail, elderly patients, particularly after invasive cardiac procedures. Furthermore, echo-labs usually also have to perform a large number of time-consuming special examinations (i.e. echocardiograms with contrast, three-dimensional studies, stress echocardiograms, transoesophageal echocardiograms and echocardiograms to aid interventional procedures) for patients with known heart disease. A reduction in the workload of the hospital porter service should also be taken into account. Certified cardiac sonographers are also essential for the effective development of this organizational model [12].

Economic considerations

In the present study, we have demonstrated that bedside echoscopy removes the need for porters and reduces required patient time by two-thirds.

Considering this economic dimension, Badano et al. have shown the improvement in the cost-effectiveness of the service provided by the echo-lab for inpatients [11]. Performing echocardiograms in the hospital ward avoided a long waiting time for inpatients in the echo-lab before and after the examination, increased the percentage of patients examined within 3 and 5 days of the request (88% vs. 77% and 100% vs. 95%, respectively; $p = 0.03$), increased sonographer productivity (by 33.9%; $p < 0.001$), increased echo-lab productivity (by 41%; $p < 0.001$) and reduced the cost of echocardiograms by 29% [11].

Potential applications and perspectives

This new pocket-sized ultrasound device can be used accurately in routine practice at the bedside for simple diagnoses such as pericardial effusion, qualitative evaluation of LV ejection fraction and morphology, vena cava diameter, etc., in a variety of circumstances (emergency, consultation, hospitalization visit) by certified physicians, sonographers or personnel with a certificate in echoscopy.

Study limitations

The image quality of the pocket-sized device did not equal that of standard complete TTE and it does not have pulsed and continuous Doppler capabilities. Therefore, it should not replace conventional TTE performed in the echo-lab but is sufficient in certain indications, such as after CABG, RFCA or pericardial drainage, to evaluate semiquantitatively pericardial effusion, LV systolic function and MR severity. Accurate measurements and evaluation with portable TTE should rely on experience in echocardiography. In our study, all analyses were performed by certified sonographers. As a consequence, skills in acquiring and interpreting the echoscopic images are recommended.

The conventional TTE evaluation inclusion was stopped at 3 weeks, compared with 6 weeks for bedside echoscopy group, because of the significance of the results in the intermediate statistical analysis and because of the evident improvement in terms of echo-lab workflow. Since then, we have used echoscopy at the bedside after all CABGs (without associated valve surgery), RFCA and pericardial drainage.

Conclusion

In conclusion, the use of miniaturized echocardiographic machines, such as the VSCAN device, avoids patient waiting time before and after the examination, patient transfer to the echo-lab and the necessity of porters.

Disclosure of interest

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

References


