History of echocardiography in the Netherlands: 30 years of education and clinical applications

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The development of ultrasound has created great opportunities for diagnostic cardiac imaging. For more than 30 years, echocardiography has been the most important and cost-effective diagnostic imaging modality in clinical cardiology. Many developments originated in the Netherlands, including the very first practical real-time cross-sectional imaging of the moving heart with a linear array. Milestones include the first portable echo apparatus, early versions of echo catheters and transoesophageal echocardiography probes as well as many clinical 'firsts' with reference to the more than 100 Dutch dissertations related to echocardiography. The future of echocardiography promises to be as productive and exciting as it has been in the previous three decades, including three-dimensional echocardiography, myocardial perfusion echocardiography, tissue Doppler imaging and speckle tracking. New potential therapeutic applications are upcoming. In this article, the advances of echocardiography in the Netherlands are described, in the past and during 30 years of education, as was recently presented by three Dutch pioneers during the 'Echomiddagen 2006-2007' organised by the CVOI. (*Neth Heart J* 2008;16: 16-20.)

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SONAR (Sound Navigation And Ranging) is based on measurement of echo travel time and was developed during World War II. It appeared quite useful for tracking German submarines. At very high (ultrasound) frequencies the same technique was used for detection of cracks in metal plates. Dr Inge Edler from Sweden used this concept in its potential application for the visualisation of cardiac structures. With the help of Dr Helmuth Hertz, a physicist, he started a project with an ultrasonic echo device borrowed from a local shipyard and recorded the echoes of his own heart. In 1954, they were the first to report the continuous recording of the motion of the mitral valve and the heart walls with a prototype called the 'ultrasonic reflectoscope' (figure 1).

From M-mode to 2D sector scan

The first documented M-mode recording dates from 29 October 1953. In the Netherlands, the group headed by Professor Nicolaas Bom in Rotterdam had a major breakthrough with the development of a multi-element linear array transducer making real-time imaging possible and they officially reported this in 1971. The only instrument available at that time provided time-motion (M-Mode) records that required pattern recognition of images, which bore no resemblance to actual cardiac structures. With even early prototype two-dimensional instruments the images actually looked like moving cardiac valves and chambers. However, it took a while before it became widely clinically available, in the form of the Organon Teknica linear scanner in 1973 (figures 2 and 3). Competition started with the mechanical sector scan which, due to the smaller transducer footprint, made it possible to take more diagnostic two-dimensional images. The electronic phased array technique had been described by Somer in 1968 for neurology. Conversion for application to cardiology took place during the 1970s.

Working in the Thoraxcentre in Rotterdam, Professor Jos Roelandt was the clinical promotor and he brought together the technical developments from Professor Bom and the clinical needs. He published his first book

Figure 1. Edler and Hertz with the reflectoscope in 1953.

Figure 3. Image result from the first ultrasonic cardiac scanner.

entitled 'Practical Echocardiography' in 1974. At that time, Professor Roelandt stated that *'noninvasive ultrasonic examinations should be increased in order to reduce the number of potentially hazardous angiograms and avoid these invasive studies entirely in specific groups of patients'*. Professor Roelandt also became the first Dutch president of the European Working Group on Echocardiography. With his clear vision, he is considered to be the godfather of clinical echocardiography in the Netherlands. At present, after his retirement, he is still the editor-in-chief of the European Journal of Echocardiography.

After the first decade of echocardiographic activity in the Netherlands, the situation in 1980 was as follows: 7% used M-mode and phased array; 32% used M-mode

Figure 2. The Organon Teknica linear echo scanner from 1973.

and linear array; 32% used M-mode only; and 29% used M-mode and mechanical sector scan (survey from Elma Gussenhoven).

Two-dimensional echocardiography was also the focus of clinical research in the Wilhelmina Gasthuis, University of Amsterdam and later the Academic Medical Centre. After his cardiology training, Professor Cees Visser went to the University of Indiana (Feigenbaum) for a research fellowship in clinical echocardiography. After his return to the Netherlands, he wrote his PhD thesis in 1982 on 'Two-dimensional echocardiography in acute and chronic myocardial infarction'. He assembled a research group of clinical cardiologists in Amsterdam, with Dr Ben Delemarre and many others, who continued to search for new clinical applications in echocardiography. In 1989,

Figure 4. Historical time survey.

Visser was appointed professor in cardiology by the Interuniversity Institute of Cardiology of the Netherlands (ICIN). Many articles and 29 dissertations were the result of his distinguished career in the field of clinical echocardiography (see list of dissertations).

The history of Doppler

Doppler echocardiography became an important component in the routine cardiac ultrasound examination based on the Doppler effect already described by Christian Doppler in 1842 (figure 4).

The Dutch physician and professor Buys Ballot from Utrecht may be considered the Dutch pioneer in this respect, describing in his famous law the patterns of deflection of the pressure gradient force, and the direction of movement. Extensive technical research on arterial Doppler took place in Maastricht by Arnold Hoeks and applications of echocardiography in congenital malformations in children was carried out by Otto Daniels in Nijmegen.

Dr Delemarre helped to further popularise the clinical application of Doppler echocardiography in the Netherlands from the mid-1980s. He defended his thesis on Doppler echocardiography in coronary artery disease in 1987. Colour flow Doppler dates back to the late 1970s and became clinically available in the Netherlands in 1985.

This was followed by the transoesophageal echocardiographic approach in 1988, which quickly developed from monoplane to biplane to present-day multiplane imaging. With the help of engineers in Rotterdam in cooperation with Oldelft, the mini-multi and micro-multitransducers were also developed.

Technology developments

In Professor Bom's laboratory, several echo catheters were designed and developed. In the early 1970s a

Figure 5. The minivisor: the precursor of today's handheld portable echo apparatus.

real-time intravascular scanner using a circular array of 32 elements at the tip of a catheter was developed. Catheter tip echo methods only gained importance after the start of Dotter techniques in the mid-1980s. A mechanical echo catheter version was produced in cooperation with Du-Med around 1988 and even a micromotor version of an echo catheter (motor diameter 1 mm) was developed, but unfortunately never manufactured. A recent product offspring of the ongoing research is intravascular elastography, the response of tissue to mechanical excitations, which is a function of its mechanical properties.

Preclinical and clinical work on three-dimensional echocardiography was performed by the Erasmus University Rotterdam and VU Medical Centre in Amsterdam, and it is clinically in use for congenital and valvular disease and quantification of left ventricular function.

Portable devices are becoming more and more important in clinical practice for rapid bedside consultation and screening. Already in 1975, the Rotterdam group headed by Professor Klaas Bom developed the 'Minivisor', the precursor of today's handheld portable devices (figure 5). Potentially, in the future, we might be able to obtain an automatic diagnosis with our 'ultrasound stethoscope'. Today, several handheld echo devices are available and increasingly being used in clinical practice.

Education in echocardiography in the Netherlands

In most European countries, echocardiograms are still performed by physicians. The concept of a non-physician performing echocardiograms is not worldwide and the Netherlands, United Kingdom and the Scandinavian countries are more of an exception than the rule. Therefore, there is a need for continuous education in cardiac physiology, anatomy and pathology as well as training in new ultrasound techniques.

The first meeting dedicated to echocardiography was held in Utrecht 30 years ago in 1977 and amongst the attendees were Professor Visser, Dr Hamer and Professor Bom. At that time, about ten people attended the initial echo meetings in Utrecht, debating the difficult M-mode recordings obtained in their laboratories (figure 6). They brought with them the A-mode (amplitude), B-mode (brightness) and M-mode (motion) recordings obtained in their laboratories from a single element crystal probe and discussed these tracings extensively.

The 'echo-middagen' have now developed into an important meeting and are visited by more than 200 people, including technicians, cardiologists in training, cardiologists and members of the industry. Initially, Job de Boo (from Utrecht, now working in Goes) chaired the meeting for several years. A great master in anatomical and interactive teaching and illustrator, Dr Hans Hamer from Groningen, chaired the 'echo-middagen' for many years, and published several educational books. He was also responsible for the promotion of the meeting towards echo technicians, resulting in a large increase in participants. His successor was Dr Ben Delemarre, and, at present, the 'echo-middagen' are being organised by the author of this review document.

Netherlands Working Group of Echocardiography and ICIN

The Netherlands Working Group on Echocardiography was established by Professor Visser, when he became a professor in clinical echocardiography for the ICIN in 1992. Later in his professional career, he became the second Dutch president of the European Working Group of Echocardiography of the European Society of Cardiology from 1996 to 1998.

Currently, about 20 active members regularly hold meetings on behalf of the Working Group of Echocardiography in Utrecht, with one representative from each university hospital or major teaching hospital participating in topics on clinical diagnosis, accreditation, quality control, education, guidelines, research and many other organisational aspects of clinical echocardiography in the Netherlands.

A surprisingly large amount of research in echocardiography has proved to be of clinical importance, some findings immediately, others after many years. This was especially because of the multidisciplinary research and close cooperation. As a result echocardiography in the Netherlands has gained a top position worldwide. Cooperation within the Interuniversity Cardiology Institute of the Netherlands (ICIN) further stimulated echocardiography through organisation of educational meetings, the creation of the Dutch working group and sponsoring joint research. Education and cooperation have always made a major

Figure 6. First M-mode echocardiogram in 1953.

contribution. The impressive result is documented in the attached list of echocardiographic dissertations in the Netherlands, listing many clinical firsts.

The future

The first use of contrast agents in echocardiography was already reported by Gramiak and Shah in 1968. Intracardiac injection of saline improved aortic delineation, probably by reflection of ultrasound by mini bubbles present in the contrast medium. Since then, microbubbles have rapidly developed into an ultrasound contrast agent in echocardiography. Dick Meltzer, working in Rotterdam at the time, used saline contrast for shunt detection in the late 1970s. Today, contrast agents are used for improved border delineation, shunt detection and Doppler enhancement, and in a research setting, for perfusion imaging of the myocardium. Furthermore, new therapeutic applications using microbubbles and ultrasound are expected. Thus, new ultrasound technologies in combination with pharmaceutical and molecular agents (microbubbles bound to genes and drugs) will create new opportunities for therapeutic ultrasound. Echocardiography is a relatively cheap and simple imaging modality. There are many new and promising developments on the horizon. Hopefully the future will be as bright as the Dutch echocardiographic history has shown to be.

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Appendix. Registered dissertations in the Netherlands on the topic of echocardiography.

A total of 104 theses have been published on echocardiography in the Netherlands. Only the first 50 are summarised here. A detailed list of all theses can be provided on request by the author (source: PiCarta, University Library VU University).

- Berkhoff A, 1964. Ultrasonic imaging in aberrating media; Simulation methods for the design of aberration correction schemes.
- Born N, 1972. New concepts in echocardiography.
- Cate FJ ten, 1978. Asymmetric septal hypertrophy (ASH): echocardiographic manifestations.
- Roelandt JRTC, 1980. Ultrasonic two-dimensional imaging of the heart with multiscan.
- Meltzer RS, 1982. Contrast Echocardiography.
- NevesdaCunha A, 1982. Pulsed Doppler echocardiography evaluation of the blood stream in children with morphological heart lesions.
- Hoeks APG, 1982. On the development of a multi-gate pulsed Doppler system with serial data-processing.
- Visser CA, 1982. Two dimensional echocardiography in acute and chronic myocardial infarction.
- Daniels O, 1982. De open ductus Botalli en Echo-Doppler onderzoek.
- Kan G, 1983. Two-dimensional echocardiographic assessment of left ventricular ejection fraction in acute and chronic myocardial infarction.
- Jong PJ, 1983. Echocardiografie bij het paard.
- Hamer JPM, 1984. Chordal rupture of the mitral valve, reappraisal of the diagnosis and treatment.
- Braat SHIG, 1984. Right ventricular infarction, its detection by electrocardiography and its effect on right ventricular ejection fraction.
- Ligtvoet-Gussenhoven WJ, 1984. Echocardiography in Ebstein's anomaly.
- Bryhn M, 1986. Left ventricular diastolic function in health and disease with special emphasis on echocardiography.
- Jaarsma W, 1987. Two dimensional echocardiographic risk stratification following acute myocardial infarction.
- Cromme-Dijkhuis AH, 1987. Echocardiographic evaluation of congenital aortic stenosis in children and adolescents.
- Lancee CT, 1987. A transesophageal phased array transducer for ultrasonic imaging of the heart.
- Koolen JJ, 1987. Left ventricular monitoring by transesophageal echocardiography.
- Delemarre BJM, 1987. Doppler echocardiography in coronary artery disease.
- Tak T, 1989. Ultrasonic tissue characterization of the heart.
- Stewart PA, 1989. Echocardiography in the human fetus.
- Algra A, 1990. Electrocardiographic risk factors for sudden death.
- Knecht, S de, 1990. Diagnosis of congenital pulmonary valve stenosis: a comparative study using multigate pulsed Doppler.
- Taams, MA, 1990. Transesophageal echocardiography for clinical decision making.
- Brink, RBA van den, 1990. Doppler echocardiographic evaluation of native and prosthetic valves.
- Rijsterborgh, H, 1990. Quantitative cardiac ultrasound.
- Herwerden, LA van, 1990. Epicardial echocardiography.
- Stümper, OFW, 1991. Pediatric transesophageal echocardiography.
- Reichert, CLA, 1991. Peri-operative applications of transesophageal echocardiography.
- Kamp, O, 1992. Transesophageal echocardiography in mitral regurgitation and coronary artery disease.
- Mooren, K van der, 1992. Doppler echocardiography in the human fetus: normal flow velocities and the effect of fetal variables [Doppler echocardiografie in de humane foetus: normale bloedstroomsnelheden en de invloed van foetale variabelen].
- Hoff ten, H, 1993. Scanning mechanisms for intravascular ultrasound imaging: a flexible approach.
- Jong, N de, 1993. Acoustic properties of ultrasound contrast agents.
- Salustri, A, 1993. Stress echocardiography.
- Arnese, M, 1994. Stress echocardiography in the evaluation of coronary artery disease.
- El-Said, EM, 1994. Dobutamine stress Doppler and echocardiography.
- Poldermans, D, 1994. Dobutamine-atropine stress echocardiography: a method for preoperative cardiac risk stratification in patients undergoing major vascular surgery.
- Hellemans, IM, 1994. Echocardiography in mitral valve surgery: a report on the ESMIR study.
- Assmann, PEMT, 1994. Quantitative analysis of left ventricular function by two-dimensional echocardiography.
- Peters, RJG, 1994. Validation of intracoronary ultrasound imaging.
- Baptista, JM, 1995. Intracoronary ultrasound, angiography and angiography in the study of plaque morphology and the mechanisms.
- Meijburg, HWJ, 1995. Transesophageal pulsed Doppler echocardiography of pulmonary venous flow: potential clinical applications related to diastolic properties of the heart.
- Dantzig, JM van, 1995. Doppler echocardiography in acute myocardial infarction.
- Pasterkamp, G, 1995. Diagnostic applications of intravascular ultrasound.
- Ryan, LK, 1995. In vitro investigation of vessel elasticity measurement with intravascular ultrasound imaging.
- The, SHK, 1995. Intravascular ultrasound in peripheral vessels.
- Bouakaz, A, 1996. Ultrasound contrast agents: in vitro acoustic evaluation and application.
- Boven van, AJ, 1996. Ambulatory electrocardiographic monitoring in stable coronary artery disease and preserved LV-function.
- Collaris, RJ, 1996. New concepts in ultrasound image processing and their potential for improving data presentation.