HISTORICAL ARTICLE

Christian Andreas Doppler: A legendary man inspired by the dazzling light of the stars

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Abstract
Christian Andreas Doppler is renowned primarily for his revolutionary theory of the Doppler effect, which has deeply influenced many areas of modern science and technology, including medicine. His work has laid the foundations for modern ultrasonography and his ideas are still inspiring discoveries more than a hundred years after his death. Doppler may well earn the title of Homo Universalis for his broad knowledge of physics, mathematics and astronomy and most of all for his indefatigable investigations for new ideas and his ingenious mind. According to Bolzano: "It is hard to believe how fruitful a genius Austria has in this man". His legacy of scientific achievement have seen Doppler honoured in the later years on coinage and money, names of streets, educational institutions, rock groups, even of a lunar crater; while the ultimate tribute to his work is the countless references to the homonymous medical eponym. Hippokratia 2013, 17, 2: 113-114

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Doppler's life and work

Christian Andreas Doppler was born on November 29th 1803 in Salzburg, Austria, and he was descended from a family of stonemasons. His apparently frail health has proven to be both a curse and a blessing as it enabled him to leave the family business and pursue higher education[1]. After completing primary and secondary school in Salzburg and Linz, he excelled in mathematics at the new Vienna Polytechnic Institute and later he studied higher mathematics, mechanics and physics at the University of Vienna[2]. At the end of his studies, he worked as assistant to Professor Burg for 4 years and was able to publish 4 mathematics papers[3]. Despite his evident talent and knowledge Doppler failed to be accepted in an academic position after the end of his assistantship and had to work for 18 months as a book-keeper in a cotton factory to support himself. During this time of disappointment he was about to immigrate to America but he was finally accepted as a professor at the technical secondary School in Prague and later at the polytechnic school of the same city[2].

During his time in Prague as a professor he married and had five children, whilst he published over 50 articles on mathematics, physics and astronomy. In 1842 he published his most famous paper Über das farbige Licht der Doppelsterne ("Concerning the Colored Light of Double Stars"), which contained his first statement of the Doppler effect. In 1947, he became Professor of Mathematics, Physics and Mechanics at the Academy of Mines and Forrests in Schemnitz, but later he and his family had to return to Vienna because of the industrial troubles[4]. In 1850, he became Full Professor of Experimental Physics and was appointed as Director of the newly founded Institute of Physics at Vienna University.

While working at Vienna, his health broke down (or betrayed him once again). Due to severe chest problems (probably tuberculosis) he had to move to Venice where a few months later, on March17th, 1953 he died in the arms of his wife.

Doppler's Principle in 1842 by C

The principle described by Doppler is the apparent change in the frequency or wavelength of a wave when there is relative motion between the source of the waves and an observer. The perceived frequency is higher (compared to the actual emitted frequency) when the source of the wave is moving towards the observer and it is lower during the recession. This apparent change in the pitch (or frequency) of sound is called Doppler effect or Doppler shift. The Doppler effect is valid for all types of waves (gamma, x-ray, ultraviolet, light, microwave, RF signals and sound) where there is relative motion.

A mathematical expression of Doppler's effect is provided by the equation: $v = c \, x \, DF / [2 \, F_T (\cos \theta)]$, where c is sound speed, DF is the frequency shift and θ is the intercept angle.

Applications in echocardiography

The Doppler effect has found practical expression in various sections of science. In astronomy, for instance, the detection of extra solar planet became reality. In addition, radars use radio waves shift from moving reflecting/scattering atmospheric targets. All these innovations have changed the conception of the world. However, it is with the implementation of the phenomenon in medical sciences than the understanding of functional parameters of human functions has drastically evolved.

Ultrasound systems display velocity, which is calculated using this equation with a process known as fast Fourier transformation. When the ultrasound beam is parallel to the direction of blood flow, cos θ equals 1 and therefore can be ignored in the Doppler equation. This is of extreme clinical importance since velocity could be underestimated when the intercept angle is not parallel, thus providing erroneous hemodynamic assessment[5].

During the Doppler interrogation two major modes are implemented in clinical echocardiography. Pulsed Wave Doppler (PW) samples velocities from a specific site, but is limited by the fact that only a limited range of velocity can be measured. Its main use lies in the recording of low-velocity signals at a specific site, such as left ventricular outflow or inflow tract. PW interrogation of transmitral flow is used by clinicians for the diagnosis and classification of diastolic dysfunction of the heart[6].

Colour Doppler imaging relies on the principles of PW. The difference is that multiple sample volumes are evaluated along each sampling line. Multiple adjacent line data are combined and a 2D image of intracardiac flow is generated. Colour Doppler recordings can be limited by the Nyquist limit, which is the maximum frequency shift measurable by PW. So when the instrument's depth is increased, the maximum speed calculated by PW is lower. Colour Doppler is a valuable surrogate for the diagnosis of valve disease and shunts[6].

Continuous Doppler on the other hand allows measurements of high-velocity signals but is unable to localize the signal's depth of origin. A clinical example of this is the evaluation of valve stenosis or regurgitation, due to its inherent ability to measure high-velocity signals. In addition, is used for the indirect assessment of pulmonary arterial systolic pressure[6].

With advent of novel high-pass filters, tissue motion can be further quantified by means of Tissue Doppler Imaging (TDI). In this modality, instead of calculating blood velocities, tissue velocities are measured, by placing a 3-5 mm sample in the basal septum, lateral LV wall or RV free wall. TDI has been implemented into various clinical scenarios, such as coronary artery disease and cardiomyopathies for the more accurate assessment of systolic and diastolic myocardial function. In addition, as proven by various studies it can be used to detect preclinical forms of several infiltrative heart diseases such as amyloidosis, sarcoidosis and Fabry's disease, despite the preserved global function these patients may exhibit[7].

Furthermore, novel echocardiographic techniques rely on TDI such as strain and strain rate imaging. These techniques study myocardial deformation throughout the cardiac cycle, providing valuable information with regards to regional myocardial function. However, these modalities are angle-dependent, hence they are susceptible to underestimation of tissue velocities and values variations exist between the various vendors. As a result, there is no consensus for their wide adoption by clinicians for patient management.

Conclusion

From the first description of Doppler phenomenon, to the 21st century renaissance era of cardiac imaging, little could anyone imagine the great impact of Christian Doppler's observation would have had on clinical echocardiography and ultrasonography in general. Doppler gave us an indispensable tool for bedside patient evaluation and clinical decision-making, as well as a valuable adjunct in medical research.

Conflict of interest

None declared.

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