The Doppler Effect: A Century from Red Shift to Red Spot

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The development of medical ultrasonography is one of the most pervasively useful advances in medical practice that has occurred in the twentieth century. The technique has many advantages over other imaging technologies, including being almost entirely noninvasive, portable, low cost, and free of ionizing radiation and of known harmful effects—safe enough that it can be used for developing fetuses. How medical ultrasound evolved from related technologies is well described in the superb article accompanying this introduction [1]. I would like to focus on a related invention in this introduction, the endoscopic Doppler probe, which has positively impacted gastrointestinal endoscopy as a result of a discovery by Johann Andreas Doppler originally published in 1842 [2], which created a paradigm shift that revolutionized fields as diverse as astronomy, meteorology, cosmology, and medicine.

In its simplest conceptual form, the Doppler effect describes how the relative motion of the source and the sensor alters the frequency of electromagnetic or sound waves. Everyone has experienced the increasing pitch of an approaching train or auto sounding its horn, which suddenly lowers as it passes, due to the compression of the sound waves produced by the train's horn as it approaches a stationary listener followed by expansion as the train or car passes and recedes. Although Doppler was correct in theory when he hypothesized that the apparent color of double stars shifts according to their velocity relative to the

Earth's, the stars' color shifts in his example were due to other factors. It required an experiment in 1845 in which the apparent pitch of trumpeters on a moving railway flatcar shifted to stationary observers that made believers out of the skeptics [3]. Like all paradigm shifts of great magnitude, Doppler attracted disbelievers and doubters, notably Josef Petzval, who questioned the veracity of Doppler's theory [3]. In any case, dying at age 53, likely due to tuberculosis, Doppler, although showered with academic honors, never lived to experience the full impact of his findings. Although many nineteenth-century scientists described red shifts of "nearby" stars, it was not until 1912 that the Doppler shift of the nebulae (galaxies) was described by Slipher [4], setting the stage for Edwin Hubble in 1932 to theorize that the universe is expanding [5], enabling physicists to calculate the Hubble constant which in turn enables calculation of astounding and stupendous dimensions and velocities such as the size of the universe, its rate of expansion, and its age. The Doppler shift has also enhanced weather forecasting in that it can precisely identify the location, the direction, and the magnitude of winds and of precipitation and RADARS (radio direction and ranging), some features of which are based on the Doppler shift. The most interest, however, for our readers is of course the medical application of the Doppler effect, which has fallen almost exclusively into blood flow measurements.

Dussik [6], who is considered to be the founder of medical ultrasonography, reported the use of the Doppler effect in ultrasound measurements, followed in 1955 by Satomura, who reported that the technology enabled measurement of cardiac valvular function [7]. Franklin et al. [8] reported that the Doppler shift correlated with blood flow. Early use of a Doppler flowprobe for measurements in the mesenteric vasculature was reported in the mid-1970s [9,

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10]. A Doppler endoscopic probe reported in 1982 by Beckly et al. [11] enabled the localization of arterial lesions in the mucosa of the gastrointestinal tract.

A recent published use of the Doppler effect in gastroenterology was reported by Jensen et al. [12], who used a disposable Doppler probe to interrogate stigmata of recent bleeding in the ulcer bed in a large cohort of patients with a history of recent gastrointestinal hemorrhage, correlating successful hemostasis with cessation of blood flow as measured by the probe.

As with all paradigm shifts, many more useful applications of the Doppler effect remain to be discovered. In the mean time, the use of endoscopic ultrasound and Doppler probes will continue to provide valuable information that will help improve the care of patients with gastrointestinal diseases.

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