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Historical Pulse Tracings Made during Anesthesia

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IT IS INDEED UNFORTUNATE when the methods by which our predecessors achieved their experimental results are lost to us. The gap between us and them, it seems, widens when we cannot understand the tools with which they worked. In his book Eckenhoff presented one such case.[1] He related that in 1881 Professor D. H. Agnew, a Philadelphia surgeon, published a textbook in which he discussed the relative safeties of chloroform and ether anesthesia.[2] To emphasize his point that ether was the safer of the two agents, Agnew illustrated his book with series of pulse curves showing a much diminished pulse in a subject fully anesthetized with chloroform (fig. 1). Eckenhoff stated that, ". . . the means by which these curves were obtained is unknown."

A practical device for recording such pulse curves existed as early as 1860.[3] This instrument, a sphygmograph, was originally described in the French literature by the celebrated physiologist Etienne Marey,[4] and again, in 1867, by the English teacher and physiologist Sir John Burdon Sanderson.[5] From their descriptions and diagrams, we are fairly certain that this device, or a very similar one, was used by Dr. Agnew. It is impossible to be absolutely certain about this point. Vierordt[6] described a pulse-writing machine in 1854, and numerous other models of the device became available about the time of Agnew's publication.[7–9] Largely because of the similarities between Agnew's illustration (fig. 1) and those obtained with a modified Marey sphygmograph by Sanderson (figs. 3 and 4), we believe that the illustrated instrument made the record.

The same engraving of the Marey sphygmograph appears in Marey's and Sanderson's books, and is reproduced here (fig. 2). The device was constructed in Paris of brass, steel, ivory and wood.[5] It was attached by a ribbon or bandage placed about the wrist and laced alternately to hooks attached to

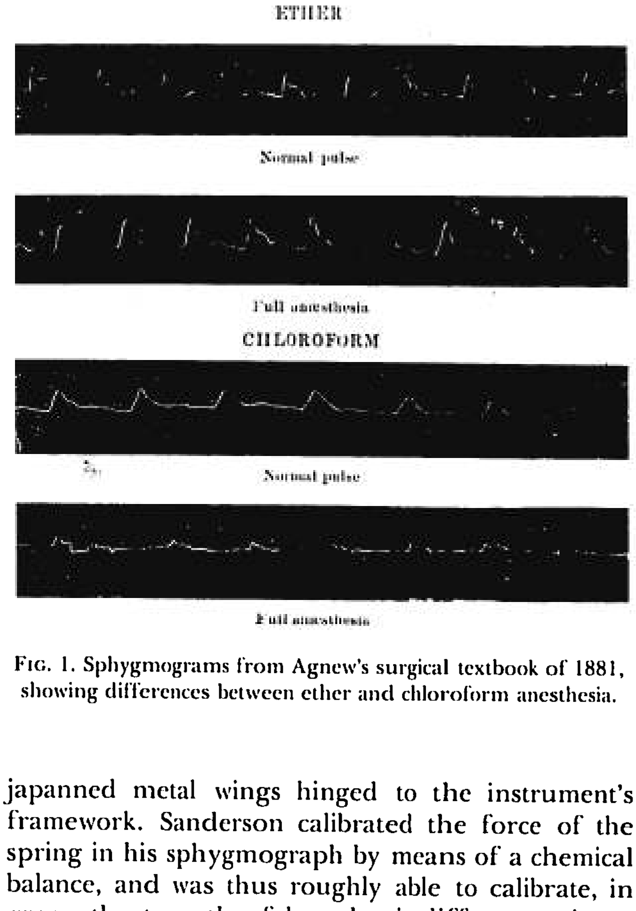

FIG. 1. Sphygmograms from Agnew's surgical textbook of 1881, showing differences between ether and chloroform anesthesia.

japanned metal wings hinged to the instrument's framework. Sanderson calibrated the force of the spring in his sphygmograph by means of a chemical balance, and was thus roughly able to calibrate, in grams, the strengths of the pulses in different patients. Measurements were usually made with a spring force of at least 100 g. This calibration process is analogous to modern measurement of the tracking force of a record tonearm by means of a balance or scale.

Sanderson also modified the sphygmograph to allow for a more secure attachment to the wrist and to enable the recording to be done on smoked glass plates. The latter modification resulted in a clearer and more reproducible record by lessening friction. The record obtained could be made permanent by varnishing it, and could be shown as a lantern slide. Sanderson's interests included the clinical application of the sphygmograph as well as theoretical physiology. His *Handbook* includes a detailed explanation of the double pulsation (dicrotism) recorded by the sphygmo-

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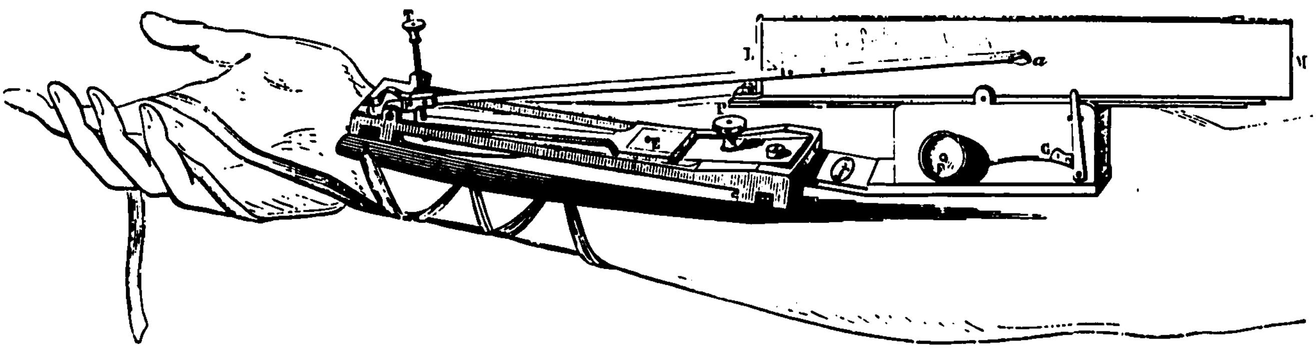
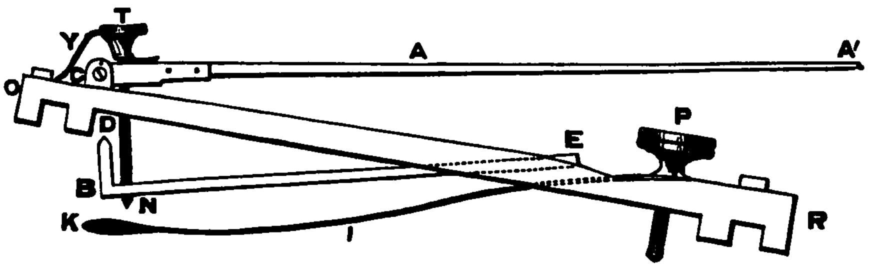


—The Sphygmograph applied to the Fore-arm.



—Enlarged view of the frame of the Sphygmograph in profile, shewing the arrangement of the levers.

FIG. 2. Marey's sphygmograph. A steel spring *I* tipped by an ivory plate *K* was applied to the skin above the radial artery. The amount of force applied by the spring and plate could be adjusted by tightening screw *P*.

The small movement of the ivory plate produced by the pulse was magnified by the two third-order levers attached to the framework. Motion was first transmitted to lever *BE* through the tip *N* of screw *T*. This lever pivoted about point *E* and transmitted oscillations through knife edge *D* to a light weight wooden lever *AA'*. This lever, in turn, pivoted on the steel screws at *C* and inscribed the pulse record on a glazed paper record, moved by a clockwork motor from *M* to *L*, "the rate of movement being such that about three inches are traversed in the tenth of a minute."

Screw *T* appears to be unnecessarily long in the engraving and also to transfix lever *AA*. The instructions for operating the device suggest that the only purpose for this screw was to adjust the distance between the ivory plate and lever *BE* and, thus, to adjust the baseline height of the scribing point at *A'*. The screw must therefore lie lateral to the wooden lever *AA'*.

graph in certain hypovolemic conditions and illustrated by the "undulatory pulse of typhus" in figure 3.

He also illustrates the very specific terms used by our forefathers to describe the pulse as palpated at the wrist. For instance, the frequency of the pulse was described as pulsus rarus or pulsus frequens, but the time occupied by each beat, not including the time between it and its successors, was described as quick (pulsus celer) or slow (pulsus tardus) (fig. 4). Furthermore, the degree of dilation of the artery was described as large or small (pulsus magnus or parvus), and the compressibility of the artery as soft or hard (pulsus mollis or duris). Even at that time, confusion of terms was a problem, as some authors had begun to describe the frequency of the pulse in terms of its quickness or slowness.

The double illustrations in figure 4 that demonstrate sphygmograms obtained at two spring pressures for the same patient are particularly interesting. Increasing the downward force of the spring sensing the motion of the radial artery would tend to limit the amplitude of the oscillations. This, in turn, would decrease the arc of the levers and the height of the record inscribed on the glass plate. Yet, Sanderson labels the tracings with greater amplitude as those obtained at greater spring pressure. Presumably, Agnew's tracings (fig. 1) were all obtained at the same spring pressures and the decreased amplitude of the records is due to pulsus parvus rather than changes in spring pressure. The full chloroform anesthesia sphygmogram also seems to demonstrate a premature cardiac contraction. Unfortunately, later studies have shown the sphygmograph to be quantitatively useless as a noninvasive blood pressure monitor, since the placement of the instrument and the thickness of tissues between the vessel and skin vary from patient to patient.

Etienne Marey's interest in sphygmography developed from studies of pulse-wave progression and the relationship between heart sounds and the various

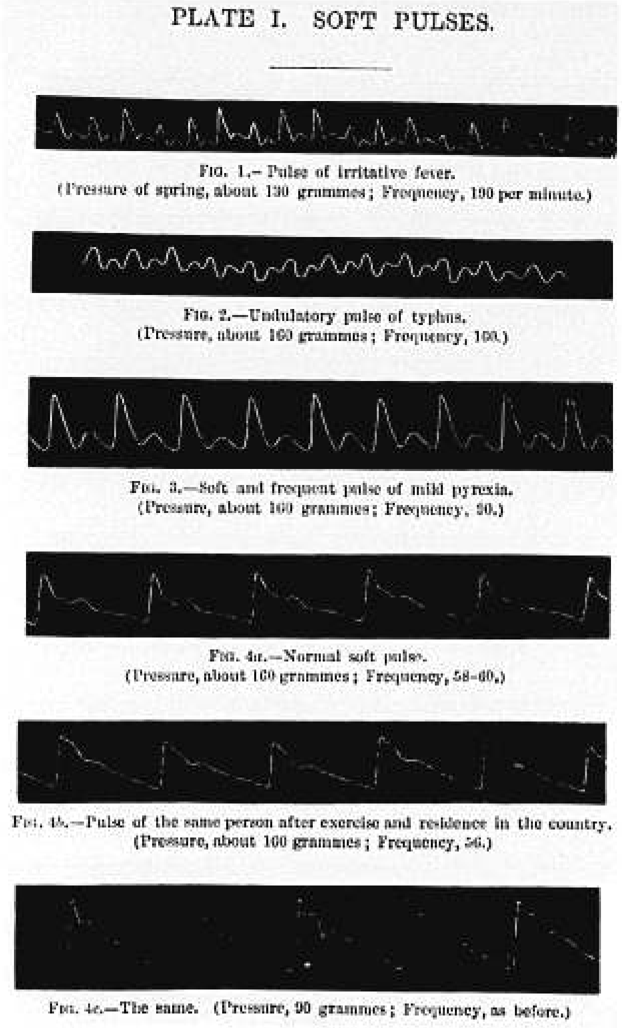


FIG. 3. Sphygmograms made by Sanderson in 1867 with his modification of Marey's sphygmograph.

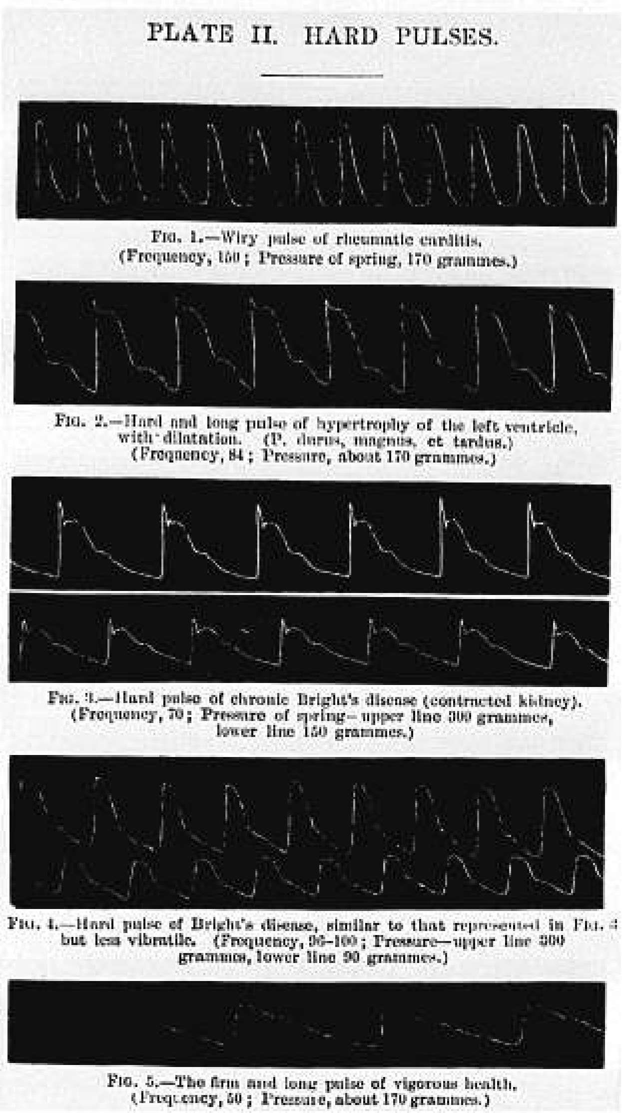


FIG. 4. Sphygmograms made by Sanderson at various spring pressures.

events of cardiac contraction carried out with Auguste Chaveau in Lyon in the early 1860's. Marey realized that the sphygmograph accurately and reliably timed the events of the cardiac cycle and that changes in the duration of these events reflected the condition of the heart.[3] Present interest in cardiac systolic time intervals has been traced to the work of these pioneer investigators and their studies with sphygmographs.[10]

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