Review Article

Stethoscopy during anaesthesia

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Purpose: First, to determine when, following the description of stethoscopy by Laennec, it was used by anaesthetists in an operating room and, second, to describe the developing possibilities for stethoscopic monitoring.

Methods: A manual search of the medical literature based on *Index Medicus* and relevant publications were obtained and analyzed. Textbooks randomly available were also read.

Principal Findings: Stethoscopy was first described early in the 20th century but was not widely recommended for anaesthesia until the 1950s. The change in attitude to stethoscopy during anaesthesia was probably due to alterations in anaesthesia delivery; increasing difficulty in employing direct human sensing. However the complexity of practice often makes traditional stethoscopy ergonomically unsatisfactory. Substantial research in the sensing and analysis of lung sounds support the contention that cheap visual displays of information from suitably designed sensors could be made available for anaesthetists.

Conclusion: Current advances in sensing, analysis, and display of lung sounds could be used to create a simple and cheap device helpful for monitoring in the operating room.

Objectif : D'abord déterminer quand le stéthoscope tel que décrit par Laennec a été utilisé par les anesthésistes en salle d'opération, et deuxièmement, exposer les possibilité qu'il offre pour le monitorage.

Méthodes : Recherche manuelle et analyse de la littérature médicale pertinente basée sur l'*Index Medicus* et la lecture de manuels choisis au hasard.

Principales constatations : L'usage du stéthoscope remonte au début du vingtième siècle mais n'a été réellement recommandé que dans les années 50. Ce changement d'attitude envers le stéthoscope est vraisemblablement dû aux modifications apportées à une façon d'administrer l'anesthésie qui est nuisible pour la surveillance immédiate. Cependant, sur le plan de l'ergonomie, la complexité de l'anesthésie a rendu périmé l'usage du stéthoscope traditionnel. Une recherche importante sur la réception et l'analyse des bruits pulmonaires supporte l'opinion selon laquelle les anesthésistes pourraient disposer d'un affichage visuel de l'information à partir de capteurs conçus spécialement et rendus disponibles à bon marché.

Conclusion: Des développements récents en rapport avec la réception, l'analyse et l'affichage des bruits pulmonaires pourraient être utilisés pour fabriquer un dispositif simple et peu coûteux pour le monitorage en salle d'opération.

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RENÉ Théophile Hyacinthe Laennec[1-4] (Figure 1) was born in France on 17 February 1781. His childhood was complicated by ill health, domestic disruption and, in 1793 during the Terror, the use of a guillotine in his village square. Parisian medical students lived harshly but by 1803 he had graduated with distinctions in medicine and surgery. His subsequent enlightened professional life was dedicated to scientific method and his patients welfare left him with little opportunity to enjoy the horse riding, hunting, and woodworking he loved.

At the beginning of the 19th century diagnosis was largely based on a patients medical history and direct auscultation of a chest was thought, by many physicians, to be disgusting, unethical with female patients and, occasionally, impossible. The circumstances that led Laennec to auscultate indirectly with a quire of paper rolled into a cylinder was a patient whose sex and age made ear to the chest auscultation unethical or, according to an apocryphal account,[5] unwise. His success led to further experiments using wood, Indian cane and other less satisfactory materials.

Laennec's treatise "De l'Auscultation Mediate" was finished on August 6, 1818[4] and published in two volumes accompanied by a wooden stethoscope (Figure 2) on August 15, 1819. (Figure 3). In January 1820 a London periodical published an anonymous 33 page review that included the statement "those who neglect to possess themselves of the work, either in the original or in the translation, inflict a deep wound on their best interest."[6] The stethoscopes were imported to England for sale by Trentall and Wurtz, booksellers of Soho, or made locally by Alnutt of Piccadilly. In 1821, John Forbes published a translation that was reduced in length from Laennec's version and had modified nomenclature. Forbes considered that physicians would appear ridiculous, transport of the device troublesome and, anyway, it could not be the sole basis of a diagnosis.[2] However, by the time of Laennec's death from tuberculosis in 1826, a second enlarged edition had been published, and he had been visited by nearly 300 students, including luminaries of English medicine. Typical English academic views were those of Sir Charles Scudamore.[7] "He (Laennec) did not advocate the adoption of physical principles in physic or intend to displace established tenets. He sought merely, by the use of the stethoscope, a simple but philosophical instrument, to reduce the excessive degree of conjecture which still prevails in the diagnosis of thoracic disease."[7] Other practitioners were less enthusiastic. The new information did not alter therapy and Laennec's descriptive analogies to sounds were too obscure for verbal instruction of students. As late as 1837, stethoscopists

FIGURE 1 RTH Laennec. From a coloured engraving reproduced by courtesy of the Wellcome Trustees (from Sakula A (3))

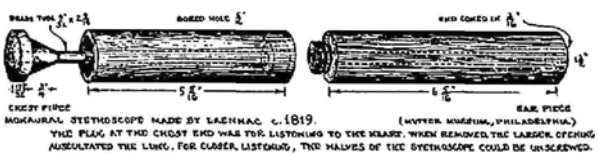
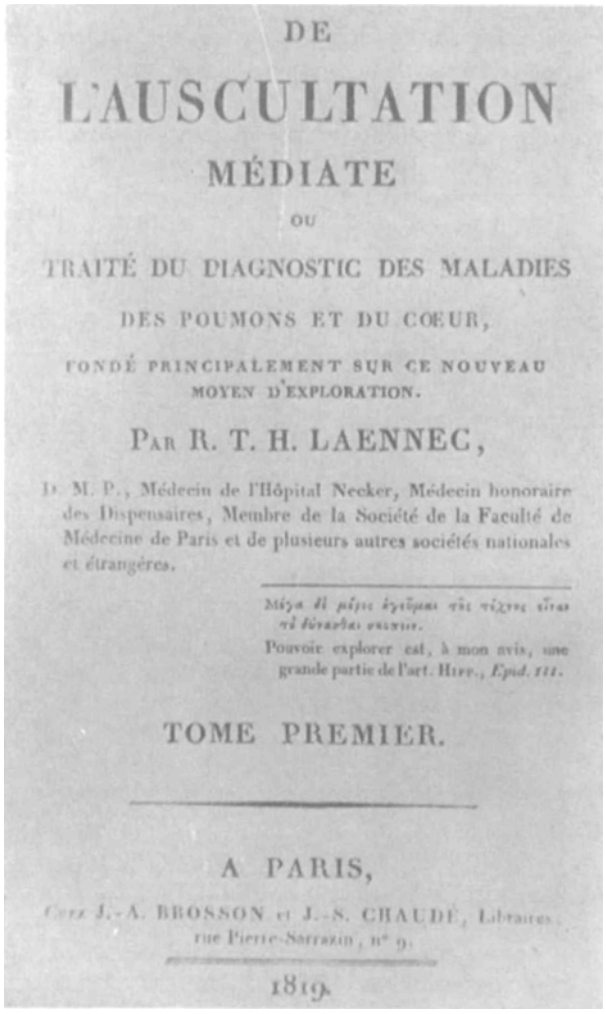


FIGURE 2 (from: Wilbur CK. Antique Medical Instruments. Schiffer Publishing Ltd. Atglen PA USA 1987.)

were a minority group against which there was considerable prejudice. However, by 1846, and the advent of clinical anaesthesia, generations of students educated in the 1820s had been exposed to the stethoscopy discipline[8] and, even by 1832, a stethoscope with a flexible tube of spiral wire covered by caoutouc cloth had been developed.[9] Many other designs during subsequent decades allegedly altered acoustic performance and convenience.[9] Ultimately in 1893 Solis-Cohen[10] described an oesophageal stethoscope. (Figure 4) This modification of a previous design by Richardson included a rubber capsule containing a diaphragm of goldbeaters skin to function as a resonator and to prevent gastric fluid from reaching the ears of the stethoscopist. Solis-Cohen's



DE

L'AUSCULTATION

MÉDIATE

OU

TRAITÉ DU DIAGNOSTIC DES MALADIES

DES POUMONS ET DU CŒUR,

FONDÉ PRINCIPALEMENT SUR CE NOUVEAU MOYEN D'EXPLORATION.

PAR R. T. H. LAENNEC,

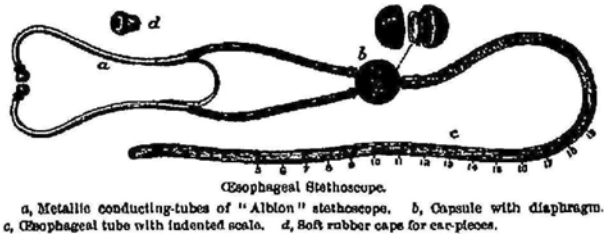
Pouvoir explorer est, à mon avis, une grande partie de l'art. HIPP., *Epid. III.*

TOME PREMIER.

A PARIS,

1819.

FIGURE 3 Title page of Laennec's De l'Auscultation Mediate 1819 (from Sakula A (2))



Œsophageal Stethoscope.

a, Metallic conducting-tubes of "Albion" stethoscope. b, Capsule with diaphragm. c, Œsophageal tube with indented scale. d, Soft rubber caps for ear-pieces.

FIGURE 4 Oesophageal stethoscope described by Solis-Cohen in 1893(10)

primary purpose for the as yet experimental instrument was cardiovascular diagnosis. Relatively recent reviews of stethoscopy exemplify the high regard in which it continues to be held in the practice of medicine.[11–16]

The purposes of the present report are to trace the arrival of praecordial and oesophageal stethoscopy into operating room anaesthesia practice and to discuss the relevance of contemporary stethoscopic developments to future anaesthetic practice.

Methods

Manual searches of the Index Catalogue of the Library of the Surgeon General of the US Army, and Index Medicus, using English language keywords: anaesthesia, auscultation, breath sounds, acoustic, monitor, and stethoscopy were done. Copies of publications relevant to the study were obtained and reviewed. A similar search was applied to randomly selected anaesthesia textbooks ranging in publication date from 1881 to 1996.

Results

Journal publications

In 1896, Kirk of Glasgow Western Infirmary[5] provided the earliest clinical account of auscultation in the operating room.[17] An ordinary binaural stethoscope sufficiently lengthened by Indian-rubber tubing was first employed. Then, a phonendoscope[9] was substituted and a watch added. Two hundred patients were studied during chloroform anaesthesia. In addition to comments on heart rate and rhythm, emphasis was placed on the finding that "the character of the pulse may be no index to the force of the heart." He was closely involved with the Glasgow Committee on anaesthetic agents. Clearly, he saw the stethoscope as a clinical research tool, a sequel to his laboratory experiments described by Duncum.[18]

This is in contrast to Cushings advocacy, published in 1908,[19] of routine continuous auscultation of cardiac and respiratory sounds during the entire course of anaesthesia. That idea arose from a practice in the Hunterian laboratory for experimental surgery and was employed clinically by the etheriser S Griffith Davis using a praecordial phonendoscope.[20] In 1924 Kane, documents surgeon and anaesthetist monitoring simultaneously the heart and, to some extent, respiration via a praecordial stethoscope (Figure 5). Kane stated specifically that the anaesthetist should have both ears blocked to avoid distractions.[21]

Three decades preceded further publications about stethoscopy and clinical anaesthesia and these concerned oesophageal stethoscopes,[22–26] breathing circuit sensing sites,[27–31] detection of air embolism[32] and its value when remote patient monitoring was necessary.[33–35] Authors also described amplification of sounds to facilitate access to them,[33,35,36–39] or video display.[40,41]

Textbooks[42–75]

The essential findings are listed in Tables I and II. It appears that between 1878 and 1955 the stethoscope, as a device to employ during anaesthesia, was ignored. However, in 1955, Knight and Tarrow[57] included one among essential equipment but its use was not described. Virtually every textbook since then has referred positively to stethoscopy during anaesthesia. In 1982, Gravenstein and Paulus[66] stated "auscultation is a relatively recent addition to the anaesthetists armamen-

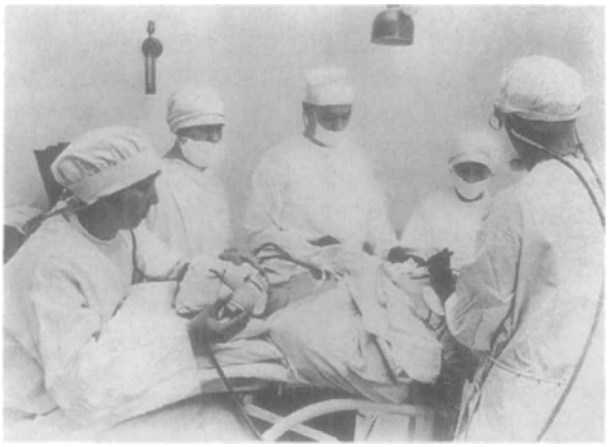


FIGURE 5 Anaesthetist and surgeon wearing a branching stethoscope 1924 (from Kane E O'N (21))

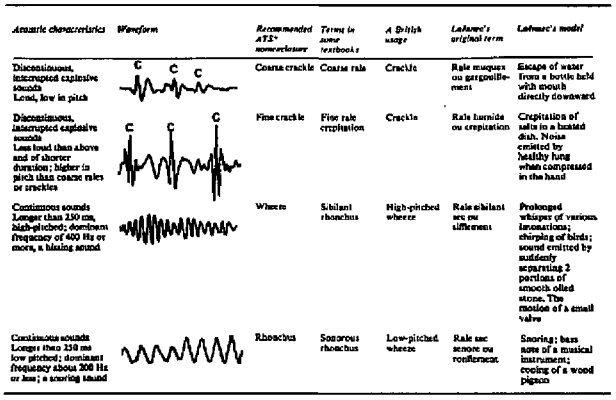


FIGURE 6 Outline of classification of lung sounds. The most recent names recommended by the American Thoracic Society (ATS) and terms used by others are shown, accompanied by acoustic descriptions and examples of typical waveforms for each category (from Murphy RL (84))

TABLE I

Author(s)			*Mention of Stethoscopes* Yes	No	*Comments*
Turnbull L	1878	(42)		+	–
Lyman HM	1881	(43)		+	–
Gwathmey JT	1914	(44)		+	–
Flagg PJ	1919	(45)		+	–
Blomfield JE	1922	(46)		+	–
Hewitt F	1922	(47)		+	–
Hadfield CF	1923	(48)		+	–
Maxon LJ	1938	(49)		+	–
Flagg PJ	1939	(50)		+	–
Goldman V	1941	(51)		+	–
Lundy JS	1942	(52)		+	–
Minnitt RJ Gillies J	1948	(53)		+	–
Macintosh RR Bannister FB	1952	(54)		+	–
Archer J	1952	(55)		+	–
AMA	1954	(56)		+	–
Knight RT Tarrow	1955	(57)	+		Included among essential equipment but use is not described
Proctor DF	1957	(58)	+		Praecordial stethoscopy for cardiac monitoring
Dornette WHL	1963	(59)		+	Ventilation meters, spectrometry, and Telecor are mentioned
Lee JA	1964	(60)	+		Described for infant anaesthesia at praecordium, oesophagus, Atkinson RS and sidearm of T piece because respiration difficult to see
Davenport HT	1967	(61)	+		Praecordial and esophageal models listed as monitors
Morrow WFK Morrison JD	1975	(62)	+		Praecordial or esophageal models for cardiac monitoring
Collins VJ	1976	(63)		+	Ignored except for sphygmomanometry
Saidman LJ	1978	(64)	+		Praecordial and esophageal stethoscopes enable essential continuous monitoring of breath sounds and heart sounds
Hug CC	1981	(65)	+		Auscultation of breath sounds listed as routine monitoring

TABLE II

Author(s)			*Mention of Stethoscopes* *Yes*	*No*	*Comments*
Gravenstein JS Paulus DA	1982	(66)	+		"The praecordial or oesophageal stethoscope which we consider an essential component of a routine monitoring" "Respiratory monitoring from the jugular fossa" "No patient should be anaesthetised without use of a praecordial or esophageal stethoscope"
Gregory GA	1983	(67)		+	Physical signs and breath sounds mentioned
Hug CC	1986	(68)	+		An oesophageal stethoscope should monitor respiration following heparin administration
Nunn JF Utting JE Brown BR	1989	(69)	+		"Hearing focused with a stethoscope still retains a key role in anaesthesia"
Taylor TH Goldhill DR	1992	(70)	+		Stethoscope is included in apparatus but only in connection with intubation
Calverley RK	1992	(71)	+		"Anaesthesiologists routinely ausculate breath and heart sounds"
Maccioli GA Calkins JM Collins VJ	1993	(92	+		Praecordial stethoscopy valuable for CV and respiratory monitoring
Runciman WB	1994	(73)	+		Ausculation of breath sounds is necessary. Advocated are praecordial and oesophageal stethoscopes with fitting ear pieces and FM transmitters
Stevens MH Shite PF	1994	(74)	+		"The simplest and most cost effective device to assist in monitoring ventilation is the praecordial, paralaryngeal, or stethoscope"
Blitt CD Hines HL	1995	(75)	+		Use of a praecordial or oesophageal stethoscope is an is an economical extension of the sensus; a means to observe the respiratory pattern, the quality of heart sounds, and a variety of accidental events

tarium but it is now firmly established practice. No patient should be anaesthetised without use of a praecordial or oesophageal stethoscope." Implicitly, those opinions were presented by Blitt and Hines[75] in 1995.

Discussion

Customarily, journal articles present new devices that, in due course, are no longer of interest to readers, so the paucity of publications during the first century of anaesthesia practice is only limited evidence that stethoscopy was little used in the operating room during that time. In contrast, textbooks provide broad evidence of current practice at the time they are published. During that time, until approximately 1955, the use of human senses was often described. Not only could useful information be obtained visually and auditorally but touch and smell were also important. In general, anaesthetists seem to have been content with the sensing possibilities available to them. There were two other reasons for lack of interest in stethoscopy. One was that its use seemed undignified and, to some, impugned the clinical competence of the user. Another was that, in days when ether or chloroform were carried on the person in elegant bottles about 10 cm high and wire framed masks often folded for convenient stowing, an unruly flexible stethoscope seemed an encumbrance. Stethoscopy was largely ignored. Thus, there is strong evidence that until post WWII only a minority of anaesthetists employed stethoscopy routinely during anaesthesia. What might account for the major change in practice at that time?

Successful entry of a monitoring device into clinical practice required:

1. A perceived need by the clinician for that kind and quality of information.
2. An ability to respond clinically to the new information.
3. Convenient use of the device.

Anaesthetists might have been content to continue indefinitely with their customary sensory information with perhaps an assistant to monitor the pulse, or sphygmomanometry that was introduced around the turn of the century. Nevertheless, other developments made this difficult. Firstly, patients were not as accessible and more people and instruments were clustered around the patient. Secondly, the advent of relaxants and manual ventilation nullified many clinical signs. Thirdly; the need for a continuous supply of vital information became increasingly apparent and anaesthetists could respond more effectively to the information they received.

Nevertheless, convenience of management with the stethoscope was a real but little documented problem. Longer operations made anaesthetists restless, as they are today[76] and though artificial ventilation by hand immobilised them at the head of the table, there were many occasions when the patient breathed spontaneously. Lengthening stethoscope tubing severely diminishes the performance and, to increase the anaesthetists mobility, short range transmitters and amplifiers[33,35,36-39] were described but failed to become popular because of noise pollution and the publicity of physiological events. More recently, in 1983, a video display of stethoscopic information during anaesthesia was described but the ergonomic problems of auscultation in the operating room remained and during this time the increasing availability of pulse oximetry and capnography reduced anaesthetists interest in it. The limitations of heart sound changes as indicators of cardiac depression were already understood.[40,77] Nevertheless, oximetry changes demand more diagnostic data, such as that provided by auscultation, as does $P_{ET}CO_2$ measurement lacking a waveform display. Moreover, there may be a clinically important delay if the system is multiplexed and under some circumstances capnography may not be possible.

The recommendations of Gravenstein and Paulus[66] as well as Blitt and Hines[75] are based on sound clinical principles. Adverse stethoscopic sounds precede functional evidence of compromised pulmonary function and complement pulse oximetry, and even capnography, for diagnostic purposes. Nevertheless, some authorities believe that, except for certain clinical situations, continuous stethoscopic monitoring is largely ignored in adult anaesthetic practice. If that is so, it is probably because it is too difficult. Other activities take precedence and amplification of sounds contributes to noise pollution. Technology that transduces stethoscopic sounds to visual displays is consistent with the unified visual displays appreciated by contemporary anaesthetists or, in its own right, supplies information from which the good clinician can predict blood gas changes. Thus, current developments in general medicine may have implications for future anaesthesia practice.

Important historical studies of acoustics associated with stethoscopy[78-82] have been followed by contemporary publications that not only include brief histories of displays of auscultatory sounds but reveal contemporary interest in them. In 1977, Murphy *et al.*[83] demonstrated visual lung sound characterization by time expanded wave form analysis and, in 1981, he related them to Laennec's model and current text book terms.[84] (Figure 6) He focused on the mechanism, production, and transmission of normal and abnormal lung sounds which themselves may vary from beat to beat, in contrast to the relative uniformity of heart beats. He concluded that if the huge amount of information contained in lung sounds could be filtered and applied, like Laennec's correlation of careful observation and auscultation, a powerful diagnostic tool would be created. Selig (1993)[85] detailed the clinical requirements for physicians hearing and the development of cardiac acoustics. He concluded with reference to heart and lung sounds that, in an age of pocket computer technology, the future capabilities of electronic stethoscopes are far reaching and can also embrace compensatory devices for selective hearing defects.

Conclusion

After the first description of a stethoscope more than a century elapsed before it was adopted by anaesthetists in the operating room. Whether this delay contributed to morbidity and mortality is moot. However, during the current practice of anaesthesia and surgery, authorities believe its use is essential. Accordingly, as respiratory acoustical measurement moves into the clinical environment, standardization of instruments becomes increasingly important.[86] Performance information should be required of manufacturers of a nature relevant to a sensor that will be directly or indirectly coupled to a chest wall.[87] The ergonomics of anaesthetic practice often demand continuous visual display of pulmonary events derived from stethoscopy and this promises to be cheaply and commercially possible[88] and, at its simplest, display relative changes in the patient under consideration. Such a device might be a transition to end tidal CO_2 waveform displays and remain an adjunct to them. Trained normal human hearing cannot be matched by instruments, and paediatric anaesthetists who remain immediately adjacent to their patients throughout the procedure may consider visual displays unnecessary or undesirable. However, the previous comments on stethoscope characteristics and on impaired hearing remain relevant.

Acknowledgments

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