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Anaesthesia monitoring: the human factors component of technology transfer

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Abstract

Resistance to change in monitoring practices from within the anaesthesiology community is a formidable obstacle, and coercive and exhortatory solutions are likely to be unsuccessful in some situations. An analysis of publications about technology transfer and professional obsolescence, and application of this data to the practice of anaesthesia, reveals various stresses that technology transfer from research areas to the workplace may induce in vulnerable anaesthesiologists and account for their attitudes. It is suggested that the invaluable pronouncements of high profile anaesthesiologist groups must be supplemented by supportive behaviour by physicians and administrators at an institutional level. The human factors issues to be addressed include: (i) Monitored data acquisition skills. (ii) Possibility of acting on monitored data. (iii) Assistance for personal insight into attitudinal difficulties that may be encountered. (iv) Data supporting the value of the device. (v) Ergonomically effective integration of the monitor into the work station.

Alternatively the perceptions of potential users may accurately reflect changes in their status in the new work situation created by monitors, and decision making aids that may or may not be derived from them. Thus, plans to present job satisfaction in related clinical areas or to associate the proposed new system with evaluation of its effect on patient outcome will be necessary. In this way the clinician becomes involved in clinical research, a quality of personal and quality care development.

Introduction

Certain statements by distinguished anaesthetists exemplify the developing use of instrumental monitoring. In 1934 the importance of defining clinical signs was emphasized [1]. "Many of us anaesthetists are tempted to make the statement to the beginner that it is just a matter of experience: the inquisitive beginner has the right to demand an explanation. Therefore attempt to analyze and put into exact words the nature of this instinct." Two years later clinical signs were coordinated in a plan of the stages of anaesthesia [2, 3]. These and lists of vital physiological signs, indicated ways in which the design of new monitoring instruments could help patient and anaesthesiologist. Such instruments began appearing more frequently in operating rooms and in 1964 anaesthesiologists were cautioned succinctly to temper enthusiasm with rationality [4]. "The anaesthesiologist and others should answer three questions before they elect to employ a monitor: (1) Do I thoroughly understand the instrument to be used, know its potential sources of error or misinformation and if it should fail for any cause, would I recognize it instantly? (2) Will the information I am to secure so involve me in technic that I will be distracted from the patient? (3) Is the information meaningful in this particular

case?" A year later a distinguished lecture about instrumental monitoring [5] concluded with the query: "Should old dogs try to learn new tricks?" The responses of the audience, if any, were not published. However, some twenty-five years later important new monitoring instruments had been developed and there was substantial evidence that, designed and located so that they themselves could be monitored diligently and pleasantly by the anaesthesiologist, would increase the likelihood of a good patient outcome [6–9]. Those findings are strongly supported by pragmatic opinions of anaesthesiologists though some devices have been controversial [10, 11]. The overwhelming opinion, however, is that specified items [6–9] be included in standards of practice or worthy of imminent inclusion. An additional, rarely mentioned, role of instruments is to antagonise fatigue by providing sensory input to the anaesthesiologist during the long periods of physical inactivity that are often the result of a well-planned and conducted anaesthetic associated with skilful surgery. Vigilance is best at moderate levels of arousal and impaired at the lower end of the inverted U which represents severely reduced sensory input, and at the upper end when sensory stimulation is extremely strong [12–19]. Currently system designers emphasize reduction, as well as efficiency, of sensory input.

Nevertheless, though new monitors have been widely adopted, a persistent attitude of a few anaesthesiologists evoked the following statement [20]: '... clinical arrogance, protected or justified by a conviction in the mystic rights of clinical freedom, lies at the basis of many serious omissions or errors in patient care ... Those who still argue that the educated finger is the most appropriate monitor must catch up with time and recognize that whatever its many uses the finger is only a finger and has very little capacity for education." The following year a lucid description of strategy for improving anaesthesiologists' patient outcome [23] ended with the following paragraph: "Resistance to change from within the anaesthesiology community are formidable obstacles. It is perhaps the mark of some individual anaesthetists who most needed to alter their practices. Peer review, peer pressure, close supervision, and standards setting by malpractice insurers, regulations and government may be the only solution to this problem."

Coercion and exhortation will not produce the desired attitudinal and behaviourial change in every anaesthesiologist, if for no other reason that for some the new requirements may stress some of them. Thus it seemed useful to identify possible stresses, in an anaesthesia context, and propose additional human factors guidelines for the introduction of new monitoring technology for operating rooms. These guidelines would supplement existing strategies for technology transfer from research and development to the work place.

Method

Monitors identified in statements of standards of care were identified from the Cumulated Index Medicus (1947–1990). Stress factors that have been associated with technology transfer were identified from reviews of technology transfer, professional obsolescence and other relevant literature, found under the major heading 'technology' and subheadings listed in the Cumulated Index Medicus during the last six years. These data were integrated to describe the user stress that might occur if use of a device was demanded without consideration of its potential effect on certain anaesthesiologists.

The chronological frequency of references to a stethoscope and its modifications were specifically noted during the period 1947–1990.

Results

Some anaesthesiologists are likely to be stressed by an inappropriate method of introducing a new monitor or monitors into the work environment. These stresses are classified as follows:

1. Health limitations diminishing anaesthetists' ability to monitor the monitor

Even if an instrument seems ergonomically well-designed certain user limitations may not have been considered. Colour blindness will hinder observation of LED monitors [22]. The pulse ox-

imeter Nellcor N-100 delivers a tone varying in pitch according to the oxygen saturation of the patients' blood. In one reported study just over 10% of anaesthesiologist subjects failed to recognise and pitch change until the saturation had fallen to 92 >91% [23].

Efforts to overcome a perception of fatigue are certainly stressful. Factors likely to cause fatigue are: intensity and duration of physical and mental work, environmental temperatures, light and noise, Circadian rhythm, domestic or professional conflicts and anxiety, pain and imperfect nutrition [12]. Any one of these can produce an anaesthesiologist with impaired judgement who does not perceive a monitor as something that reduces stress by improving the frequency, character and quality of information about the anaesthesia delivery system and the patient. On the contrary the monitor may be perceived as one more burden to an already difficult life.

2. Inability to act on the knowledge provided by the monitor

If the previous education of the anaesthesiologist has not included interpretation of the data provided by the monitor, then a stressful situation exists. It is a manifestation of information anxiety [24] that occurs in many occupations as well as the practice of medicine. A stressful sequel is the inability to provide appropriate therapy because, though diagnostic help in the form of the monitor is present, appropriate drugs or equipment are absent [25].

3. Fear of substitutive innovation

In any occupation, once training is complete, there is a natural reluctance to apparently lose face by admitting ignorance, fatigue, or the need for help [17, 26]. Indeed, an anaesthesiologist who is proud of clinical abilities may feel diminished by the presence of an instrument that he or she is told will do the task better. The job satisfaction that may already be at a low ebb is perceived as reduced unless the manner in which the instrument augments the ability to function as a good anaesthesiologist is fully appreciated.

4. Public display of undesirable physiological events

Well-designed displays of instrumentally monitored data that accommodate attempts during long operations to combat vigilance decrement by adopting varying locations in the operating room are obvious to other members of the operating room team. This is standard practise in many surgical units where such information is often used by the surgical team as well as the anaesthesiologist, but under other circumstances it may be stressful for some to realise that an undesired physiological event, albeit temporary, is now public knowledge [27].

5. Data acquisition conflict

Monitor, systems, and work station design must enable the anaesthesiologist to acquire the data necessary for effective patient management conveniently. If the new monitor not only increases workload but inflicts new decisions about where to look next and how long it is safe to look, only a startlingly valuable device will make the newly induced stress worthwhile.

A relationship between instrumental monitors and the stresses that may be induced in certain anaesthesiologists is summarized in Tables 1 and 2. The judgements regarding the potential for each of the four stresses were based on: (i) the likelihood that the necessary knowledge to interpret the data delivered by the monitor is a requirement for medical licensure, (ii) the likelihood that knowledge and facilities for action on the data exist in that work environment, (iii) probable familiarity with the device in the operating room environment, and (iv) likely manner of data delivery. It appears that though each monitoring instrument could produce each of the stress factors in a susceptible person, the ECG and instruments for gas and vapour analysis would be most likely to be so. The instruments with the least likelihood are the stethoscope and pulse meter or plethysmograph. Generations of physicians have used stethoscopes but publications about the stethoscope have continued to appear in anaesthesia journals during the past forty years (Fig. 1). Recent emphasis is on design that facilitates the acquisition of information from multiple

Table 1.

	Health limitations hinder monitor data acquisition by anaesthesiologist	Anaesthetist's current knowledge precludes assessment of data provided by monitor	Anaesthetist's current equipment precludes action on assessment of data provided	Fear of substitutive innovation	Open display of physiological data about the patient
Systemic blood pressure. (Automated sphygmomanometer)	This depends on the character and magnitude of limitations on the manner in which information is made available to the anaesthetist	–	±	–	+
Cardiac electrical activity. (ECG)			±	+	+
Inspiratory and expiratory gas and vapour concentrations. (Mass spectrometer)		Knowledge acquired at medical school may need to be relearned or augmented	±	+	+
Haemoglobin oxygen saturation. (Pulse oximeter)		–	±	+	+

sites by an anaesthetist busy with other duties in the operating room.

Discussion

The welfare of patients in the operating room can be served by the wise introduction of technology for monitoring purposes. A product life cycle en-

Table 2.

	Health limitations hinder monitor data acquisition by anaesthesiologist	Anaesthetist's current knowledge precludes assessment of data provided by monitor	Anaesthetist's current equipment precludes action on assessment of data provided	Fear of substitutive innovation	Open display of physiological data about the patient
Peripheral tissue perfusion. (Pulse oximeter or plethysmograph)	This depends on the character and magnitude of limitations on the manner in which information is made available to the anaesthetist	–	±	+	±
Pulse rate/rhythm. (Pulse oximeter or plethysmograph)		–	±	+	±
Breath sounds. (Stethoscope and modifications)		–	±	–	±
Heart sounds. (Stethoscope and modifications)		–	±	–	±

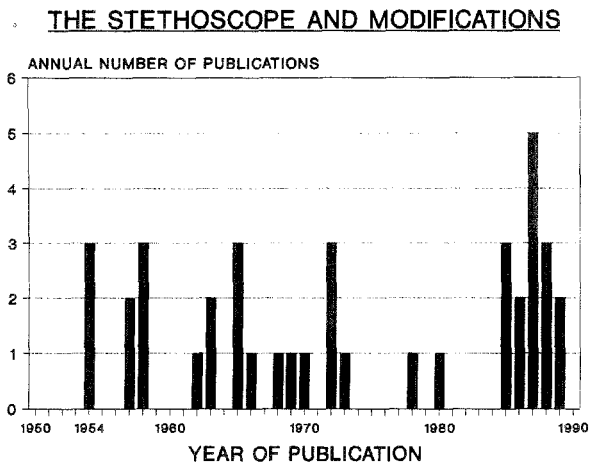

Fig. 1. The stethoscope and modifications.

compasses the original idea, development, trial, dissemination, and loss of favour. The persons involved in this transfer are scientists and clinicians functioning as researchers and educators, and clinicians who may ultimately adopt the instrument under consideration if their environment provides that option. The initial process of this transfer is referred to as technology assessment and is multidisciplinary [28] as well as multifactorial: technical performance, clinical efficiency, cost and efficiency, acceptability and attractiveness, research value, effects on the medical care system, ethical issues and larger societal effects [29]. 'Human factors' encompasses the variety of matters influencing the varying attitudes of new users of technology that has reached the potential adoption stage, or that has been actually been placed in operating rooms. It is an alternative to 'acceptability and attractiveness' when the subcategories of technology transfer are listed.

The validity of using stress identifying criteria that have not been described specifically for anaesthesiologists in operating rooms is justified by the similarity of the task and environment to some industrial and transportation occupations as well as personality variations among persons working in them. The relationship described between stress and monitoring device is merely judgemental, lacking statistical support because numerical data does not as yet exist. It could be strengthened by consensus among a group of anaesthesiologists and other forms of investigation. Nevertheless, existing knowledge of anaesthetic practice justifies the intuitive belief in such a relationship.

If the attitude of the potential user of a new monitoring device is largely determined by that person's perception of its usefulness and any increase in personal stress produced by its use, the prolonged popularity of the stethoscope is easily comprehensible. This monitoring device provides diverse and some unique information, especially if the system conveniently delivers it from different parts of the thorax, and it is still an important feature of medical education. Evidence of contemporary interest are attempts to present stethoscopic data in a more convenient manner than has been the case hitherto [30–33]. The pulse oximeter reduces the anaesthetists' stress, producing as it does vital information about oxygenation and perfusion conveniently, and with greater accuracy and frequency, than can be attained with traditional clinical methods such as visual estimation of oxygenation and arterio-capillary filling time. However, it can be personally perceived as an instrument that threatens the anaesthesiologist and the clinical judgement that is believed to have served him or her and the patients adequately for a long time, though the limited quality of such data from that judgement is evident [34–40]. The electrocardiograph and measurement together with a graphic display of inspiratory and expiratory gas and vapours are likely to require specific postgraduate training for the anaesthesiologist and appropriate facilities in the operating room and recovery room to use the data presented. Anaesthesiologists lacking these skills and opportunities will be stressed and the instruments wasted unless these hazards are offset. Essential features of a successful instrument are not only that it reduces the work stress of the anaesthesiologist by increasing the likelihood that a successful patient outcome can be achieved, but that it does not add to the stress factors inherent in the task of anaesthesia.

Finally, the personalities of anaesthesiologists differ [41] and influence the stress responses to a monitoring instrument, which in turn will affect the effective integration of a new device into the anaesthetic practice of the small group of anaesthesiol-

ogists under consideration [21]. Professional obsolescence is a term referring to the result of failure to participate effectively in continuous career education subsequent to achieving a specified level of training. To some persons it seems comfortable, normal, satisfactory and rational, to let competence and skills decay and this is tolerable to them [42]. One of three categories of professional obsolescence portrays an individual who tends to substitute judgement for scientific evaluation and is hostile to innovations [43]. In the middle years of life overbearing problems may absorb energy and attention and attempts to cope with those take precedence over what seems an inconsequential matter of changing what is perceived as perfectly adequate task performance.

Conclusion

There is strong evidence that exposure to a new monitoring instrument in the operating room can stress an important minority of anaesthetists to such an extent that the instruments are used imperfectly or not at all. Changes in practice are advocated by gatherings of high profile anaesthesiologists whose professional guidance and assistance in obtaining financial help is invaluable. However, it is impossible for their final reports and editorials to address the needs of every anaesthesiologist who is expected to comply effectively with recommendations or regulations. Local informed guidance and support is necessary for every anaesthesiologist. Legal precedents regarding responsibilities for this will eventually occur, but clearly they include persons additional to the physician conducting the procedure [44].

The process of transferring monitoring devices from development to the specific hospital workplace must include local consideration of the stress that they may induce in the anaesthesiologist expected to use them. The responsibility for arranging this lies largely with the institutional administration and physicians responsible for CME in the institution or the region. The factors that must be addressed in this human factors aspect of technology transfer are: (i) the effect of health limitations on ability to monitor the monitor; (ii) the ability of the user to act on the kind of information provided by the monitor; (iii) the presentation of data supporting the value of the new device with specific reference to any equivalent human performance; (iv) information about possible professional attitudes that will assist personal insight into difficulties encountered; and (v) the possibility of the monitor being integrated with the anaesthesiologist's work station in an ergonomically effective manner.

If the perceptions of users interpret reality accurately and do not reflect attitudinal problems created by the presence of new technology, then changes in the work environment are very likely to be necessary. These may involve: education, duty periods, additional personnel to prepare equipment for use, responsibilities into new areas. As an example of this last, total intravenous anaesthesia that is automated and computer-based may apparently hinder efforts to demand a physician's level of education for anaesthesia care in the operating suite and even diminish the status of physicians working in the operating room. This can be offset by involving them in responsibility for acute pain management throughout the hospital, a burgeoning development for which anaesthesiologists are well suited. Another example may apply to computer-based assistance for clinical decision making. Institutional medical care is dominated by quality care reviews and cost effectiveness studies. This reflects on overall desire by physicians and by persons that the best possible patient care be available. Computer assisted decision making, provided it is associated with a matched arrangement for collecting data about the patient outcome, does not detract from the physicians status or job satisfaction. Indeed, it provides interesting and useful new insights into patient care by facilitating the following of research protocols for studies of patient care.

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