muscle activity or myoclonus.[14] In all of the reported cases of "seizures," the patients have received less than 50 μg/kg fentanyl. This suggests that low to moderate doses are responsible. Perhaps the patients of Murkin *et al.*[13] failed to exhibit myoclonus because the fentanyl plasma concentrations were high enough to rapidly produce high concentrations in the entire neuraxis, thus depressing lower central nervous system centers as well as higher inhibitory centers.

Another explanation is that these movements are only exaggerations of narcotic-induced muscle rigidity.[15] Narcotic-induced muscle rigidity can occur after very low doses of fentanyl.[16,17] It involves all muscle groups[18] and, in pronounced form, might resemble a seizure. Such pronounced rigidity as to resemble a seizure may occur only rarely and, thus, was not seen in the eight patients reported by Murkin *et al.*[13]

In summary, we report the absence of cortical seizure activity in an EEG recording during an apparent "seizure" observed in a 73-year-old man receiving a fentanyl infusion. The peak fentanyl serum concentration was 32.0 ng/ml. We attribute this abnormal motor activity either to myoclonus produced by narcotic depression of higher central nervous system inhibitory centers or to a pronounced form of narcotic-induced rigidity.

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Acoustic Transmission of Low-frequency Sounds

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Auscultation of heart and blood pressure (Korotkoff) sounds are commonly employed methods of monitoring in clinical anesthesia. The ability to hear these extremely low-pitched sounds (20–300 Hz)[1,2] depends upon several factors: volume and frequency of the sounds, collection by the stethoscope bell, transmission by the usual combination of stopcocks and plastic tubing to the anesthetist's ear, and, of course, the hearing acuity of the anesthetist. All of these factors have been investigated except for the influence of the connecting tubing/stopcock combinations on transmission. The purpose of this study was to compare the acoustic transmission of low-frequency sounds using materials commonly employed in clinical practice.

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Key words: Monitoring: auscultation, stethoscope.

METHODS

Twelve healthy volunteers between the ages of 27 and 50 years (mean 34 ± 8 SD) underwent audiometry to determine aural acuity at a frequency of 125 Hz. This was performed by an audiologist, utilizing a Maico MA-24® audiometer calibrated quarterly. In accordance with standard practice, the volume (db) of the 125 Hz tone was varied randomly while the subject, seated in a soundproof room, acknowledged hearing the tone by pressing a button. Values were recorded in decibels of hearing loss (db HL), better hearing indicated by lower numbers.

A Littman Model 2101® stethoscope was prepared by cutting the single tube joining bell and earpiece sections and fitting the cut ends with metal male and female connectors sized to interface with standard iv connecting tubing. The bell section then was held gently to form a seal with the audiometer earphone, and the audiometry was repeated, with sound traveling through the bell section and 22 cm of connecting tubing connected to a molded earpiece. The earpiece then was replaced with the Littmann® binaural stethoscope earpiece section and audiometry repeated. A stopcock was interposed between the bell and stethoscope earpieces and audiometry again was repeated. Various lengths and types of tubing then were interposed between the stopcock and stethoscope earpieces and the hearing threshold recorded.

Intravenous tubing used was the Extension Set®, 30″ (Abbott Laboratories, North Chicago, Illinois). Oxygen tubing was cut from Inspiron Nasal Cannula sets (C. R. Bard, Inc., Rancho Cucamunga, California) into 76- and 120-cm lengths. The ends were fitted with metal male and female connectors compatible with standard iv connections.

Differences between the hearing thresholds obtained using the various equipment combinations were analyzed using analysis of variance and Duncan's multiple range test.

RESULTS

TABLE 1. The Effects of Different Devices upon Sound Conduction

	Hearing Threshold db HL (mean ± SD)
Single ear (audiometer earphones)	15.4 ± 4.5 A*
Bell + molded earpiece	15.8 ± 3.6 B
Bell + binaural stethoscope earpieces (BSE)	10.4 ± 4.5 C
Bell + stopcock + BSE	10.4 ± 3.3 D
Bell + stopcock + 76 cm iv tubing + BSE	11.2 ± 4.3 E
Bell + stopcock + 76 cmO_2 tubing + BSE	10.0 ± 3.7 F
Bell + stopcock + 120 cmO_2 tubing + BSE	10.8 ± 3.6 G

* AB > CDEFG ($P < 0.05$).

The effect of the various sound conducting devices upon hearing threshold are shown in table 1. All subjects had hearing threshold at 125 Hz within the normal range of 0–20 db HL. The monaural earpiece gave the same threshold as the single ear baseline value. There was a significantly increased threshold (decreased hearing acuity) ($P < 0.05$) when using the monaural molded earpiece compared with the binaural sthethoscope earpieces (BSE). The use of the bell and binaural stethoscope earpieces increased hearing acuity significantly ($P < 0.05$) compared with the single ear baseline threshold using the audiometer earphones. The addition of the stopcock and various lengths and types of tubing between the bell and earpiece had no effect on threshold. No correlation was found between age and threshold.

DISCUSSION

The increased hearing acuity (decreased threshold) shown in this study using the binaural stethoscope earpieces can be explained by two factors: the approximately three-decibel increase in acuity with use of both ears compared with the single ear,[3] and the better seal that the spring-loaded binaural stethoscope earpieces form compared with the molded earpiece, which tends to slip loose. This problem of slippage can be overcome by applying manual pressure to the molded earpiece, forcing it into the external ear canal, creating a better seal.

It was somewhat surprising that introducing the stopcock and various lengths of plastic tubing between the stethoscope bell and earpiece had no detrimental effect upon acoustic transmission. A common recommendation in stethoscope design is that the length of all connecting tubing be as short as possible.[4,5] This is true for optimal transmission of high-frequency sounds, which are rapidly filtered out as tubing length increases. Low frequencies in the range of heart and Korotkoff sounds, however, are readily transmitted via longer tubing lengths.[4]

Another factor that may favorably influence the transmission of heart and Korotkoff sounds in clinical practice is the effect of resonance. Low-frequency sounds have wavelengths several meters long (2.75 m at 125 Hz, for example, as was used in this study). Like all sounds, they exhibit increased amplitude at points along the conducting tube corresponding to lengths of ¼, ½, 1 or 2 times the wavelength. Therefore, several low-frequency components of Korotkoff and heart sounds (55, 110, and 220 Hz) will be resonant at a tubing length of 120 cm, the longest length tested in this study. This phenomenon probably compensates for some of the loss of sound energy that occurs with increasing lengths of conducting tubing, even in low-frequency sound transmission.

The effect of learning response upon test performance possibly may have biased the results of this study. The order of testing was uniform, such that the longer tubing lengths were tested at the end of each study session. The test subjects, therefore, may have gained some improvement in hearing level by improving their testing skills over the 15-min session.[6] This could obscure an actual decrease in sound transmission using the longer tubing lengths. The magnitude of this learning response is not well defined in the audiology literature. In the experimental setting described here (little motivation to perform well and a short test period), it is probably no more than 1–2 db, which borders clinical significance (1 db being the smallest change in sound level detectable by the human ear). Also, the finding that the bilateral stethoscope earpieces provide a 5 db gain in hearing level over the monaural earpiece, which is in agreement with previously reported data,[3] occurred too soon in the session (less than 5 min from the beginning) to be significantly biased by learning response.

I conclude that the use of an appropriately sized stethoscope bell and binaural spring-loaded earpiece allows optimum transmission of low-frequency sounds in the range normally encountered in clinical practice. The use of a stopcock plus iv or oxygen tubing extensions of the normal sort commonly employed in clinical practice do not adversely affect the anesthetist's ability to monitor these critical sounds.

Implications of these findings, which have been borne out in clinical practice, are that if heart and Korotkoff sounds are inaudible with the commonly used monaural molded earpiece, then auscultation may be significantly improved utilizing the binaural stethoscope earpieces. The cost of doing this is loss of input from the rest of the operating room. Under these circumstances, a reasonable compromise is the intermittent use of the stethoscope earpieces. Perhaps of greater usefulness is the finding that, as opposed to previous recommendations,[4,5] increasing the length of the connecting tubing between the patient and the earpiece (up to 120 cm, a generous length) does not significantly decrease the anesthesiologist's ability to hear, while mobility and convenience are greatly facilitated.

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Intracranial Subdural Gas: A Cause of False-positive Change of Intraoperative Somatosensory Evoked Potential

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Scalp-recorded somatosensory evoked potentials (SEPs) are useful in preventing brain injury during intracranial operations.[1–4] A decrease in amplitude and increase in latency of SEPs characteristically occurs in both animals and humans during hypoxia within neural tissue.[1,7–8]

We present two patients in whom intraoperative

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