

Previous studies have suggested that arterial catheters placed by surgical cut-down carry significantly greater risks of complications than those arterial catheters placed percutaneously.^{4,12,13} Band and Maki¹² found a nine-fold increase in bacteremia in adults when arterial catheters were inserted by cut-down rather than percutaneously. Miyasaka *et al.*⁴ reported 48% of the pediatric patients with radial artery catheters placed by cut-down developed perfusion-related complications. The results of this study would suggest that in infants and children in whom percutaneous radial arterial catheter placement fails, percutaneous femoral artery insertion may be safer than radial artery cut-down.

In conclusion, the femoral artery is a comparably safe and acceptable site for arterial monitoring in infants and children. The incidence of sepsis and perfusion-related complications associated with femoral artery catheters in this age group is no greater than the incidence previously reported for radial artery catheters. In contrast, in neonates, the incidence of perfusion-related complications was considerably greater and may exceed the complication rate associated with radial artery catheterization.

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A Comparison of Aperiodic Analysis of the EEG with Standard EEG and Cerebral Blood Flow for Detection of Ischemia

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The 16-lead electroencephalogram (EEG) is a frequently used method for direct monitoring of cerebral function during general anesthesia because it is sensitive

to hypoxemia and ischemia under stable conditions of anesthetic depth, partial pressure of carbon dioxide (P_{aCO_2}), and brain temperature.¹ Monitors that process the EEG signal have been developed to simplify recognition and interpretation of EEG changes. The purpose of this study is to assess the accuracy of one of these new devices, the Lifescan™ EEG Monitor (Neurometrics™, San Diego, CA) in detecting cerebral ischemia.

The Lifescan™ uses aperiodic analysis,^{2,3} which maps each waveform in relation to its frequency, amplitude, and time of occurrence rather than averaging a large number of waveforms over a given epoch. The EEG signal is divided into three components: 1-8 Hz, 9-30 Hz, and a composite signal having the potential to contain spikes. Following conventional electroencephalographic practice, each component measures the period of each wave, which

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TABLE 1. Results Showing EEG Change and rCBF versus Lifescan™ Interpretation

Number of Cases	EEG Change	rCBF (ml · 100 g ⁻¹ · min ⁻¹)	Lifescan™ Change by Anesthesiologist		
			A	B	C
5	+	1, 2, 5, 6, 9	+	+	+
1	+	6	+	-	+
1	+	3	-	-	+
1	+	6	-	-	+
1	+	9	+	-	-
1	-	31	+	-	-
1	-	38	-	-	+
5	-	5, 7, 7, 8, 8	-	-	-
23	-	10-36	-	-	-
11	-	No data	-	-	-

rCBF = regional cerebral blood flow.

is the time between valleys. The computer also detects wave peaks, zero-crossings, and length of time between valleys, which is the period of the wave. Frequency is the reciprocal of the period. A wave is defined by detecting a valley, then a peak, then another valley. "Slow" and "fast" waves are detected differently. Detection of slow waves requires the presence of zero-crossings between the highest peaks and lowest valleys; detection of fast waves requires only consecutive peaks and valleys.

The EEG signal is obtained from a five-lead, dual-hemisphere, disposable electrode system. Both hemispheres are displayed on a full-color, high-resolution screen as three-dimensional parallelograms with frequency versus amplitude on the x-y axes and time on a diagonal axis. The memory capability is up to 24 h. A built-in four-color pen plotter produces a print-out of either real time or stored data.

METHODS

This study was approved by our Institutional Review Board. Fifty patients undergoing elective carotid endar-

terectomy were studied. For the EEG, two ear and 19 scalp electrodes were applied using the international 10-20 system of placement. The five Lifescan™ electrodes were placed with one each over the frontal and mastoid areas bilaterally and a reference electrode in the midline frontally. Regional cerebral blood flow (rCBF) measurements were obtained prior to and following carotid occlusion using washout of ¹³³Xenon.⁴ A continuous tracing of the 16-channel EEG was obtained by a technician and evaluated by an experienced electroencephalographer who had access to the rCBF results. At the time of carotid occlusion, a baseline print-out of the Lifescan™ screen was obtained showing the 5 min prior to occlusion. Three and one-half minutes after occlusion, another print-out was obtained showing the prior 5 min. These print-outs were later evaluated separately by three anesthesiologists who had a few weeks experience with the Lifescan™ and who were blinded to patient identity, rCBF results, and EEG interpretation.

Anesthetic management included thiopental and pancuronium iv and maintenance with inhalation of 0.5-1% inspired isoflurane in a 1:1 ratio of oxygen/nitrous oxide, with ventilation controlled to keep PaCO₂ within normal limits. Fentanyl was used in approximately one-half of the cases, the average dose being 175 µg iv.

RESULTS

Of the 50 cases studied, nine patients showed EEG changes at the time of occlusion with rCBF of 9 ml · 100 g⁻¹ · min⁻¹ or less (table 1). In five of those cases, all three anesthesiologists interpreted the Lifescan™ as showing a change at occlusion (fig. 1). In the other four cases, there were false negative interpretations by one or two anesthesiologists in each case. In addition, in two cases where the EEG and rCBF showed satisfactory perfusion at occlusion, the Lifescan™ interpretation was falsely positive by one anesthesiologist in each case. In five cases in which

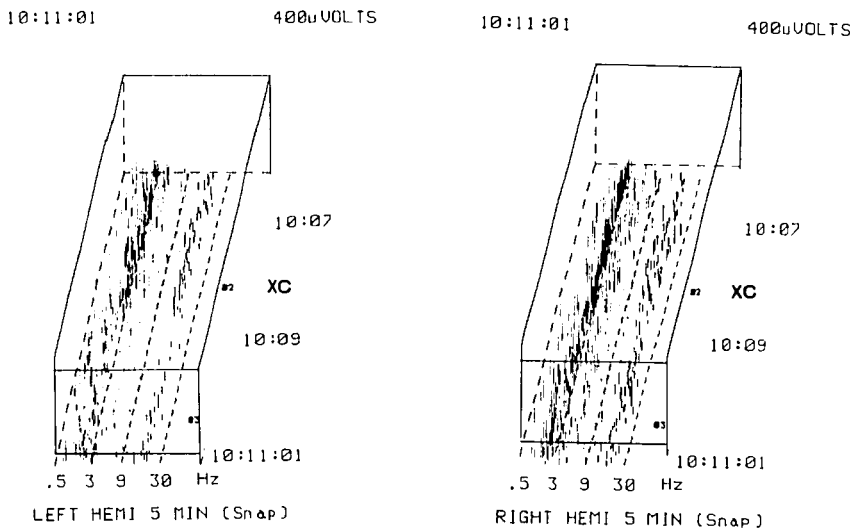


FIG. 1. This photograph of a Lifescan™ printout was obtained approximately 3 min after occlusion (marked "XC") of the left carotid artery. Frequency is displayed on the x axis with a nonlinear scale. The amplitude of each mapped EEG wave is a vertical "pole" and is referred to the top of the transparent box, which is 400 µV. Time is displayed on the diagonal axis with most recent time at the bottom front of the box. The display represents 5 min of EEG data and shows attenuation of activity on the left with occlusion that is more apparent in the higher frequency range. The EEG showed a similar change. The rCBF with occlusion was 9 ml · 100 g⁻¹ · min⁻¹.

the EEG interpretation and the Lifescan™ interpretations were all negative, the rCBF ranged from 5 to 8 ml · 100 g⁻¹ · min⁻¹, which is borderline critical flow when using isoflurane.⁵

There was no difference in arterial blood pressure at occlusion, PaCO₂, fentanyl given, or level of inspired isoflurane between those cases that showed a change in the EEG and those that did not.

The value of a new test is best understood by comparing it with the current "gold standard." This is done by calculating the sensitivity, specificity, and predictive values of a positive or negative new test result. For this study, each anesthesiologist plus Lifescan™ was considered to be a separate test (table 2). The sensitivity is the per cent of cases with ischemia that were correctly identified by the Lifescan™ readers. The specificity is the per cent of cases without ischemia that were identified properly with the Lifescan™. The predictive value of a Lifescan™ change is the proportion of those with a change who had EEG changes. The predictive value of a "no change" Lifescan™ interpretation is the proportion of those with a negative test who had no EEG changes.

The sensitivity data shows that about three-fourths of patients who developed ischemic changes following carotid occlusion were diagnosed using the Lifescan™, with variation from 56 to 89%, depending on the anesthesiologist. The predictive value of a "no-change" Lifescan™ interpretation shows that when no change was seen, it had a 95% chance of being correct.

In addition to making a "yes-no" statement about a change in the Lifescan™ at occlusion, each reader was allowed to make comments. Out of a possible 150 comments, 19 revealed some degree of uncertainty on the part of the interpreter. Four of these occurred with false negative interpretations, two with false positives, and the other 13 with true negatives.

DISCUSSION

One of the problems of this study is that the Lifescan™ Monitor is similar to the 16-lead EEG in that the interpretation is based on the overall picture rather than on a numeric output, which makes it subject to the experience of the reader. Thus, this study is as much a test of the anesthesiologists as it is an assessment of the monitor. However, it was felt that this would be closer to the true clinical situation and therefore probably a more valid assessment of the actual use of the monitor.

TABLE 2. Detection of Ischemia Using Lifescan™

	Anesthesiologist		
	A	B	C
Sensitivity (%)	78	56	89
Specificity (%)	98	100	98
Predictive value of change (%)	88	100	89
Predictive value, no change (%)	95	91	98

Another major difficulty of the study design was that in order to blind the anesthesiologists, the print-out was used as the basis of interpretation rather than the real-time, scrolling picture on the screen. The Lifescan™ screen uses five colors to represent the processed EEG, while the printer represents the same information in only three colors. In addition, it was felt that being present to observe the changes on the screen during induction and during varying anesthetic depth would be a distinct advantage in deciding what occurred with cross-clamp over having to make a decision based on a print of only a few minutes duration. Thus the results in the clinical setting could be somewhat different than those shown by this study.

We have shown that under the conditions of this study, the Lifescan™ EEG Monitor can be used by relatively novice interpreters with fair accuracy to determine the presence of cerebral ischemia at the time of carotid occlusion. We feel that the Lifescan™ would be a useful addition to monitoring during carotid endarterectomy in institutions where monitoring of electrical activity of the brain is currently not being done. Other monitors that process the EEG signal are available and need to be compared with the standard 16-channel EEG to evaluate which equipment is most effective.

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