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Carboxyhemoglobin and Pulse Oximetry

To the Editor:—The use of pulse oximetry is a standard practice in the operating room and intensive care because of its accuracy, noninvasiveness and ease of use, but it has some limitations. Barker and Tremper[1] have recently reported erroneous pulse oximeter readings (oxygen saturation [Sp_{O_2}]) in dogs exposed to carbon monoxide. They established that since the light absorbance spectra of carboxyhemoglobin (COHb) and oxyhemoglobin are similar in the red wavelength range, the pulse oximeter is unable to differentiate between them. Thus, in the presence of COHb, the instrument may seriously overestimate arterial blood oxygen saturation (Sa_{O_2}). Based on these experimental data, the authors concluded that the pulse oximeter should be used with caution in patients with a possible recent history of carbon monoxide inhalation.

We have had the opportunity to verify this assumption in two patients in whom a diagnosis of carbon monoxide intoxication was made. The two patients, a 51-yr-old female and a 55-yr-old male, were admitted comatose and stuporous, respectively. The only abnormal laboratory results found were the arterial blood gases (IL 1302 Gas Analyzer) (table 1). A history compatible with carbon monoxide poisoning was related by relatives. The Sp_{O_2} readings (Pulse Oximeter 7840, Kontron Instruments) on admission were 96 and 99%, whereas COHb levels were 32 and 22.7% and Sa_{O_2} were 66.1 and 77%, respectively (IL-282 Cooximeter). Hyperbaric oxygen treatment at a pressure of 2 atm was initiated in both patients. After 2 h of treatment, COHb levels were 1.1 and <1%, respectively. Measured Sa_{O_2} and Sp_{O_2} were now similar and >95% (table 1). The patients were awake, and there was no further deterioration.

These two cases illustrate the clinical implications proposed by Barker and Tremper: the pulse oximeter is not useful in assessing the oxygenation of patients intoxicated with carbon monoxide.

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TABLE 1. Blood Gas Measurements

Time	Patient	Sa_{O_2}	COHb	Sp_{O_2}	P_{O_2}	P_{CO_2}	*p*H	Hb
Admission	1 (F)	66.1	32.0	96	88	28.9	7.30	17.6
	2 (M)	77.0	22.7	99	71	26.1	7.30	15.5
2 h after treatment	1	97.4	1.1	96	223	32.2	7.40	—
	2	99.0	<1	98	153	27.0	7.43	—

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Train-of-four Ratio Is Not Always Independent of Stimulating Current

To the Editor:—In a recent study, Brull *et al.*[1] have compared train-of-four (TOF) ratios by mechanomyography using 20, 30, and 50 mA currents delivered to the ulnar nerves of volunteers and patients receiving nondepolarizing muscle relaxants. The authors concluded that ". . . T_4/T_1 testing can be accomplished reliably in patients without using a supramaximal stimulus."[1] They claim to show that TOF ratio is unchanged regardless of the stimulating contact used. However, they have manipulated their data in an improper way to arrive at this conclusion.

Brull *et al.* state in their methods section, "If a T_4 response was not obtainable at a given current (as was the case for nine of 28 intraoperative assessments at 20 mA), then the subject was excluded from the main study population because the T_4/T_1 ratio could not be calculated."[1] I take issue with this statement because a TOF ratio *can* be calculated if $T_1 > 0$ but $T_4 = 0$. In that case, $T_4/T_1 = 0$. Thus, Brull *et al.* have conveniently discarded all T_4/T_1 ratios of 0. They then proceed to use the TOF ratios on these same individuals at 30 and 50 mA. If, as they should have, Brull *et al.* had included individuals with

$T_1 > 0$ and $T_4 = 0$ (*i.e.*, $T_4/T_1 = 0$) but with $T_1/T_4 > 0$ at 30 and 50 mA, the result would have refuted their conclusion regarding the constancy of TOF ratio at different currents. It is also possible that under other conditions, TOF ratio may be 0 at 30 mA but greater than 0 at 50 mA.

The lack of constancy of TOF ratio at 20, 30, and 50 mA suggests that a supramaximal stimulating current should be used in monitoring the neuromuscular blockade.

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Doctor . . . Are You *Sure* the Patient Is Paralyzed?

To the Editor:—The role of peripheral nerve stimulation in the clinical assessment of neuromuscular blockade, and the implications of submaximal stimulation on the evaluation of T_4/T_1 ratio (train-of-four [TOF]) were recently examined by Brull *et al.*[1] They state that the original motivation for the investigation was the systematic discovery and subsequent concern that several nerve stimulators in their operating room suites delivered currents of only 16 mA.[2] In assessing neuromuscular function in awake or recovering patients, the authors' data support the conclusion that submaximal stimulation is adequate for TOF evaluation in the interest of patient comfort. Yet, in the abstract accompanying this article, they state "that T_4/T_1 testing can be reliably accomplished *intraoperatively* and postoperatively using submaximal stimuli" [emphasis added]. This belief is evident throughout the article. Are "underpowered" nerve stimulators adequate for assessing neuromuscular function intraoperatively, as suggested by these investigators?

Careful reading of their article exposes interesting data secluded in the methods section; a T_4 response was unobtainable with a 20-mA stimulus in 9 of 28 anesthetized patients maintained on a continuous vecuronium infusion: a reliable T_4/T_1 ratio was attained in *all* subjects only at 30 mA or greater. These 9 were excluded from analysis in the 20-mA category (submaximal stimulus), and are never discussed again. This intraoperative population represents a statistically significant group of nonresponders to a 20-mA stimulus ($P < 0.001$; chi-squared = 33.3 as compared to 30 or 50 Hz).

Lee carefully described the need to stimulate at 2 Hz and at a spacing of 0.5 s to maximize the information gathered from the TOF.[3] Kopman and Lawson showed that requirements for obtaining a maximal twitch in *all* patients when stimulating the ulnar nerve at the wrist *via* surface electrodes was at least 20 mA, or 2.75 times the current necessary to illicit the first detectable twitch.[4] Thirty milliamperes provided supramaximal stimulation in *all* patients regardless of wrist circumference. Combined with the data from Brull *et al.* establishing that 32% of intraoperative subjects cannot be assessed for a T_4/T_1 ratio with a 20-mA stimulus, this finding lends strong credence to the conclusion drawn in 1984: "Inadequate stimulation [current] may lead the clinician to overestimate the degree of neuromuscular blockade present."[4] Adequately designed stimulators that can deliver high continuous current (>30 mA) will guarantee that the anesthesiologist can confidently assess the patient during *all* phases of anesthesia care. Despite the attempt of Brull *et al.* to reassure themselves and us to the contrary, the nerve stimulators lurking in New Haven, Connecticut should be cause for concern.

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In Reply:—We were somewhat perplexed by Dr. Lawson's concern that "underpowered" nerve stimulators are "lurking in New Haven," especially in light of his paper in which it is stated that "of the commercially available battery-operated nerve stimulators available in the United States, most have maximum outputs no greater than 30 milliamperes (mA)."[1] We emphasized that the major focus of our work[2] was not the assessment of the stimulating power of nerve stimulators, but rather the determination of whether submaximal currents may be used deliberately for train-of-four stimulation so as to reduce discomfort in the awake patient.

Although Lawson notes that 30 mA provided supramaximal stimulation of the ulnar nerve *via* surface electrodes in his 38-patient study,[1] we found that there was a difference in the height of the first twitch as current increased from 30 to 50 mA in our 83-patient sample. However, whether or not 30 mA constitutes supramaximal stimulation is beside the point; this question does not address the main message of