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Effects of Intravenously Administered Dyes on Pulse Oximetry Readings

MARK S. SCHELLER, M.D.,* RICHARD J. UNGER, M.D.,† MICHAEL J. KELNER, M.D.‡

Pulse oximetry has emerged as an easily applied, noninvasive, and continuous monitor of arterial oxygenation in the perioperative period.[1] Various physiologic and environmental factors have been described that interfere with accurate determination of oxygen saturation (S_{O_2}). These include high-intensity light, patient movement, electrocautery, diminished perfusion, the administration of vasopressors, cardiopulmonary bypass, dyshemoglobinemias, and hypothermia.[2] We have observed a number of patients in whom iv-administered dyes appeared to be associated with abrupt decreases in pulse oximetry S_{O_2} readings despite Pa_{O_2} in excess of 100 mmHg. A recent case report has also drawn attention to this phenomenon.[3] This study was undertaken to quantitate the magnitude and duration of these effects as measured by the Nellcor® N-100 S_{O_2} monitor in volunteers given one of three commonly used iv dyes.

MATERIALS AND METHODS

Following Human Studies Committee permission and informed consent, 15 paid volunteers were studied. The subjects breathed room air and were supine with the head elevated 30°. Monitoring consisted of an automated blood pressure cuff with a 1-min cycle and a continuously displayed electrocardiogram. An iv infusion of 0.9% saline was established in a hand vein. Nellcor® pulse oximetry finger probes were applied to the index finger of the hand contralateral to the iv infusion site and to the right large toe. These were connected to separate N-100 Nellcor® pulse oximetry monitors. When pulse oximetry readings appeared stable, one of three dyes was injected as a bolus into the briskly running iv line. The solutions injected were 5 ml of 1% methylene blue, 5 ml of 0.8% indigo carmine, or 5 ml of 0.25% indocyanine green. Pulse oximetry readings were recorded every 5 s for 5 min. The time from injection to the first noticeable decrease in S_{O_2} readings (latency), the lowest S_{O_2} reading (nadir), and the time required to return to baseline (duration) were noted for each subject from each of the two sensing locations.

Dyes were diluted 1:1000 with saline and placed in a spectrophotometer. Absorbance spectra of the three dyes were plotted on standard coordinates.

RESULTS

Fifteen white subjects were studied, five with each of the three dyes. Dye administration was well tolerated. No change in heart rate or arterial blood pressure was observed in any subject following dye administration. Subjects given methylene blue, however, did report pain at the iv site on injection, which persisted for about 1 day. Baseline S_{O_2} readings were 97 or greater in all subjects in both the toe and finger locations. Subject characteristics, latency, nadir, and duration are summarized in table 1 for each of the three dyes.

Of the three dyes, indigo carmine produced the fewest and smallest changes in S_{O_2} readings. Decreases from baseline were observed in three of the five subjects given indigo carmine, but only in the toe location. The magnitude of the S_{O_2} reading decreases were small following indigo carmine. The lowest S_{O_2} reading observed in any subject was 92%. By contrast, S_{O_2} reading decreases were observed in all subjects in both sensing locations following the administration of methylene blue. The median lowest S_{O_2} reading (nadir) was 65%. The lowest S_{O_2} reading observed following methylene blue was 1%. In subjects given

* Assistant Professor of Anesthesiology.
† Resident in Anesthesiology.
‡ Assistant Professor of Pathology in Residence.

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Address reprint requests to Dr. Scheller: Neuroanesthesia Research Laboratory, M-029 La Jolla, California 92093.

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methylene blue, S_{O_2} readings remained below baseline for between approximately 1 and 2 min in both the finger and toe. S_{O_2} reading decreases following the administration of indocyanine green were intermediate between those observed with methylene blue and indigo carmine.

Absorbance spectra for the three dyes as determined by the spectrophotometer are plotted in figure 1.

Discussion

These data demonstrate that iv-administered dyes can cause sudden decreases in Nellcor® S_{O_2} readings. The time course of the latency for these changes is approximately one or two circulation times (30–45 s), and recovery to baseline readings occurs within 3 min of bolus dye administration in healthy, young subjects breathing room air. S_{O_2} reading decreases from baseline were largest following the administration of methylene blue and least following the administration of indigo carmine.

The Nellcor® pulse oximeter operates on the same principle as other commercially available devices. Light of two wavelengths, 660 nm and 925 nm, is emitted by light emitting diodes (LEDs), passed through tissue, and sensed on exiting by a photodetector. Arterial pulsations in the tissue change the length of the light's path and thus the amount of light detected.[3] The relative absorbances of oxygenated and unoxygenated hemoglobin also influence the amount of the different wavelengths of light detected by the photodetector. The device combines all of this information to display a pulse waveform and arterial S_{O_2}. Any substance in the blood or tissue that absorbs light of the same wavelength produced by the LEDs can potentially alter the amount of light sensed by the photodetector and can therefore alter S_{O_2} readings. The Nellcor® instruction manual makes reference to this point.

All three dyes absorb light in the region of the 660 nm wavelength light emitted by one of the LEDs. Figure 1 demonstrates that methylene blue has an extremely high absorbance in this region. This explains why methylene blue interferes to a greater degree with S_{O_2} readings than the other dyes. Likewise, the absorbance of indocyanine green is slightly greater than indigo carmine at this wavelength, which is consistent with the observation that S_{O_2} readings were affected to a greater degree in those subjects given indocyanine green than in those given indigo carmine.

All subjects received the same amount of dye, *i.e.*, 5 ml. The variable responses of the individual subject's S_{O_2} readings following dye injection may have been related to differences in cardiac output or blood volume. For example, following methylene blue, the largest S_{O_2} reading decrease and longest duration of decrease was seen in the smallest subject (body surface area = 1.34 m^2). The measurement of cardiac output by the transcutaneous detection of various intravenously dyes has been studied in both adults and children and found to correlate well with dye dilution methods that use continuous arterial blood sampling, particularly if the sensing densitometer is dichromatic.[4–6]

Studies examining the usefulness of sensing iv-administered dyes transcutaneously with S_{O_2} monitoring technology for the purposes of estimating cardiac output, circulation time, or blood volume may be indicated on the basis of these preliminary observations.

Although Nellcor® S_{O_2} readings returned to baseline quickly in our young, healthy subjects, this may not be the case in very young, elderly, debilitated, or heavily

TABLE 1. Subject Characteristics and O_2 Saturation Reading Responses to IV Dyes

Dye	Weight (kg)	Height (in)	Latency (s) Finger/Toe	Duration (s) Finger/Toe	Nadir (O_2 saturation) Finger/Toe
MeBl	75	70	80/65	70/90	91/80
	68	69	35/30	105/80	58/65
	79	72	40/40	65/50	76/59
	93	71	40/35	50/50	80/69
	46	64	35/30	115/80	1/32
InGr	83	74	35/45	10/40	96/96
	67	69	45/40	35/25	95/93
	70	70	45/35	45/70	93/84
	86	75	50/45	70/30	93/92
	70	69	NC/65	NC/60	99/88
InCa	83	74	NC/NC	NC/NC	NC/NC
	67	70	NC/40	NC/40	NC/93
	46	64	NC/25	NC/30	NC/92
	86	69	NC/NC	NC/NC	NC/NC
	65	68	NC/20	NC/20	NC/94

MeBl = methylene blue; InGr = indocyanine green; InCa = indigo carmine. NC = no observed change.

Latency = time to initial fall (s). Duration = time from initial fall until return to baseline (s). Nadir = lowest O_2 saturation reading observed.

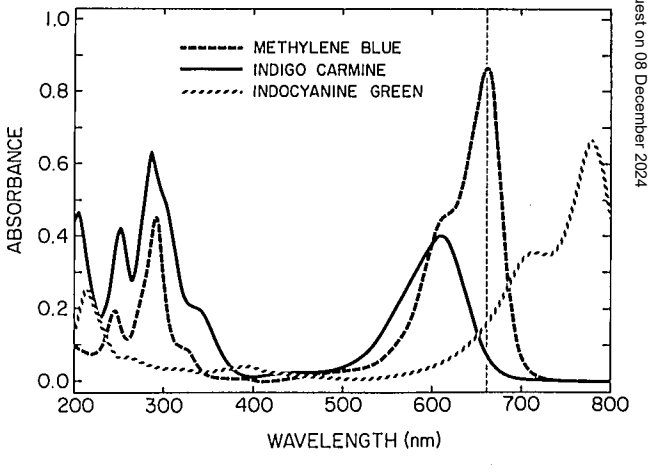

FIG. 1. Absorbance spectra of the three intravenously administered dyes. Note the *dashed line* at 660 nm that corresponds to one of the wavelengths emitted and sensed by the Nellcor O_2 saturation monitor.

pigmented patients in whom bolus injections of the dye have been administered.

Practicing anesthetists should be aware of the potential influences of intavenously administered dyes on S_{O_2} monitor readings so that operating room time is not wasted and more invasive analysis not undertaken, *e.g.*, arterial blood gases, should falsely low S_{O_2} readings be temporarily induced by administration of these dyes.

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Common Peroneal Nerve Palsy Associated with the Fabella Syndrome

YUKIO KUBOTA, M.D.,* YOSHIRO TOYODA, M.D.,† HIROSHI KUBOTA, M.D.,‡
HIDEO KAWAI, M.D.,§ TOMIO YAMAMOTO, M.D.¶

Most cases of postoperative nerve palsy result from malpositioning of the patient on the operating table, with consequent stretching or compression of nerves.[1] We describe an unusual postoperative common peroneal nerve palsy in a patient maintained in the supine position during surgery.

Report of a Case

A 50-yr-old woman was scheduled for elective exploration of the common bile duct. Her past history was unremarkable except for cholelithiasis and a cholecystectomy. Physical examination and laboratory tests, including analysis of arterial blood gases, were within normal limits. Her body height was 147 cm and body weight 44 kg. The electrocardiogram revealed normal sinus rhythm with flattening of the T wave in leads II, III, aVf, V_5, and V_6. She received secobarbital 75 mg, atropine 0.5 mg, and meperidine 17.5 mg, im for premedication. Anesthesia was induced with thiopental 250 mg and pancuronium 4 mg, iv. Following endotracheal intubation, anesthesia was maintained with enflurane, nitrous oxide, and oxygen. Respiration was manually controlled or assisted throughout the operation. Removal of intrahepatic stones and transduodenal sphincteroplasty was performed. She was in the supine position with a leg strap applied tightly above her knees without knee supports for 6.25 h. The trachea was extubated when she was fully awake at the termination of surgery. In the immediate postoperative period, she complained of pain on the dorsum of her right foot. No trauma to the foot was found.

On the afternoon of the first postoperative day, the patient noticed weakness of the foot on walking to the lavatory. On the third postoperative day, she complained of numbness and inability to dorsiflex the foot; the pain had subsided slightly. Neurologic examination revealed complete paralysis of all muscles innervated by the common peroneal nerve. The lateral aspect of the leg and dorsum of the foot had no sensitivity to pin prick. A mass (5 × 5 mm) was palpable on the posterolateral aspect of the right knee. Localized tenderness and pain, present over the common peroneal nerve, were accentuated by direct pressure on the mass. A lateral roentgenogram of the knee showed the presence of a fabella (fig. 1). An electromyogram was suggestive of a compression syndrome. Her orthopedic surgeon recommended excision of the fabella, but the patient refused; subsequently physiotherapy was instituted. On the 28th postoperative day, an electromyogram revealed volitional motor unit potential with fibrillatory potential of tibialis anticus, the peroneus, and extensor digitorum muscles. Nerve conduction on the common peroneal nerve from proximal to the fabella to the ankle was 21.0 m/s and between fibular head and ankle was 37.8 m/s, indicative of delayed conduction velocity at the site of the fabella. On the 84th postoperative day, all muscles innervated by the common peroneal nerve revealed modest recovery of motor strength from grade 0 to 3 on manual muscle testing and slight recovery from numbness of her right leg and foot.

Discussion

Britt[1] asserted that the common peroneal nerve is the most frequently damaged nerve in the lower limb. The

* Chief, Department of Anesthesia.
† Associate Chief, Department of Anesthesia.
‡ Staff Member, Department of Anesthesia.
§ Staff Member, Department of Orthopedic Surgery.
¶ Chief, Department of Orthopedic Surgery.
Received from Departments of Anesthesia and Orthopedic Surgery, Osaka Kohseinenkin Hospital, 4-2-78, Fukushima, Fukushima-Ku, Osaka, Japan 553.
Address reprint requests to Dr. Kubota.
Key words: Position: nerve damage.