

adhesive tape, or finger<sup>4</sup> are also alternatives to emergency airway management to obtain a functional ETT. However, once this condition is allowed, the ETT exchange should be performed as soon as possible.<sup>4</sup>

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## Ultrasound Guidance: Concerns and Safety Issues May Have Some Answers

*To the Editor:*

The letter by Cory<sup>1</sup> brings to attention the importance of being aware of the bioeffects of ultrasound. It is a topic close to my heart and hence was exciting to read. Some of his queries may already have an answer. I would like to highlight some of the changes in the past few decades that he may have missed by oversight.

The safety concerns based on more than four decades of animal research prompted many organizations including American Institute of Ultrasound in Medicine and other international organizations to perform an in-depth analysis of this issue to arrive at conclusions and recommendations.<sup>2-5</sup> These have been mostly comforting in that no human studies have yet identified a potential risk. But they all do warn about the need for continued vigilance, especially with the use of currently available ultrasound machines with capabilities for higher outputs.

The other change that has happened is the display of indices for potential harm. The Food and Drug Administration mandated that machines with higher acoustic outputs

display the thermal and mechanical indices to qualify for track 3, which shifted the responsibility of monitoring to the end user.<sup>6</sup> These calculated indices based on the data derived from animal studies are worst-case scenario estimates for potential harm. Most modern machines are programmed to limit the indices by changing the pulse repetition frequency, the pulse duration, and so forth.

Various animal models of crush injury to nerves followed by insonation have shown faster recovery of function besides histologic signs of earlier myelination when compared with sham.<sup>7-9</sup> Ultrasound bioeffects on the nervous tissue seems to span from neurolysis with high-intensity focused ultrasound to changes in ion channels besides changes in amplitudes and latency with therapeutic ultrasound.<sup>10-12</sup> All these changes were demonstrated at higher intensities or at least the upper limits of the diagnostic ultrasound intensities. Citing the capabilities of ultrasound to cause neurolysis may be an extreme as one should not be denied the use of the excellent image guidance that ultrasound provides.

Although animal studies have shown myriad effects with insonation, many well-conducted epidemiologic studies have failed to demonstrate causality.<sup>13,14</sup> The claims about autism, dyslexia, and handedness with ultrasound exposure have been disproved by studies including a longitudinal follow-up of children whose mothers had more than one exposure to ultrasound during pregnancy.<sup>14</sup>

Many animal studies have shown the potential for non-thermal effects with ultrasound including inertial and non-inertial cavitation especially in gas-containing bodies.<sup>15</sup> Ultrasound has been shown to produce high temperatures and also generate free radicals during cavitation.<sup>6</sup> But the threshold for both inertial and noninertial cavitation is lowered only with microbubble contrast agents and not with the larger bubbles as may be encountered during injections.<sup>16</sup> Cavitation, a frequency-dependent phenomenon, may be unlikely with the bubbles that he refers to.<sup>17</sup> It is further reduced as the radius of the bubble required for cavitation at the higher frequencies used in regional anesthesia and pain medicine becomes restricted to a very narrow range.<sup>6</sup> A small study looking at lung hemorrhage during transechocardiography found no intraoperative evidence of lung hemorrhage as seen in animals.<sup>18</sup> Human lung seems to be protected from nonthermal effects because of factors yet unknown.

As he mentions, the attenuation coefficient changes with fluid or injectate. Using the National Council for Radiation Protection deration may provide safety with low attenuation. But most importantly, keeping the indices and the duration of insonation within limits especially during use of power Doppler, a stationary mode, may be all that is necessary.<sup>6</sup> During the use of ultrasound guidance for regional anesthesia and pain medicine, mostly the B mode is used with constant movement of the transducer until the target is identified.

I do agree with him that the low-intensity values that ultrasound machines claim is derived and sometimes differ between machines, as all the manufactured machines do not

undergo standardization and only some machines undergo the laborious acoustic parameter assessment in the laboratory. This is mainly for cost and time savings, but the difference is likely to be small. But practicing vigilance may help to detect the unknown or an extremely rare event.

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## Safety of Ultrasound-guided Regional Anesthesia

### To the Editor:

Four years ago, *ANESTHESIOLOGY* published a clinical concepts and commentary article that reviewed the use of ultrasound guidance for regional anesthesia.<sup>1</sup> This article described the underlying principles and available literature of this nascent field. General efficacy and safety of these approaches have been borne out in a large number of subsequent clinical trials.<sup>2</sup> However, a recent letter to the editor has raised the theoretical concern that bioeffects may be harmful to patients undergoing regional anesthesia procedures guided by ultrasound.<sup>3</sup>

Although it is clear that there are thermal and mechanical bioeffects of ultrasound, there are no confirmed adverse bioeffects when diagnostic levels of ultrasound are used.\* Most bioeffects simply dissipate during the duty cycle of pulse sequence ultrasound and are significantly attenuated by the perfusion of living tissue.<sup>4</sup> Moreover, when using a handheld probe for imaging during peripheral nerve block, it would be very unlikely for a transducer to be maintained in a fixed position for an extended period. Interestingly, some of the postulated bioeffects of high-intensity ultrasound actually include the promotion of nerve regeneration and conduction block,<sup>5,6</sup> two effects potentially beneficial to those patients undergoing regional anesthesia procedures. Nonetheless, prudent use of ultrasound means using the lowest levels of exposure to achieve the desired goals (as low as reasonably achievable principle).

When studied *in vitro*, the threshold for ultrasound producing reduction in peripheral nerve compound action potentials was approximately 100–200 W/cm<sup>2</sup> (continuous wave, 30-s burst, reported intensity as the spatial peak temporal average).<sup>7</sup> This reduction correlated with nerve temperature elevation from ultrasound exposure and was more pronounced at low frequencies. Irreversible effects only occurred at more than 400 W/cm<sup>2</sup>, well above the current Food and Drug Administration imposed limit of 720 mW/cm<sup>2</sup> (intensity as the spatial peak temporal average) for diagnostic imaging.<sup>8</sup> Admittedly, the interaction between local anesthetic toxicity and ultrasound has not been experimentally studied by such models, and the concerns that have been raised will hopefully encourage such investigations.

\* Statement on mammalian *in vivo* ultrasonic biological effects. Available at: <http://www.aium.org/publications/statements.aspx>. Accessed December 6, 2009.