When patients undergo general anaesthesia, they might feel as if they are entering an oxygenated and carefully monitored diving bell. They entrust their lives to the anaesthetist, who lowers them gently into the depths of oblivion for the duration of the surgery. They are entering an oxygenated and carefully monitored diving bell. When patients express dread of awakening prematurely in the elderly, we comfort them that such iatrogenic locked-in experiences are not attenuated in mice expressing isoﬂurane resistant γ-aminobutyric acid type-A receptors. Neurosci Lett 2007; 420: 209–12


The diving bell and the butterfly

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diaphragm’. Despite this seemingly harrowing account, Mayrhofer does not describe being distressed, probably because he anticipated these sensations and the duration was brief. With widespread usage of succinylcholine, however, it was soon discovered that about one in 2000 people experience prolonged paralysis or ‘scoline apnoea’. By providing a model enriched postoperative weakness among surgical patients admitted to practice is associated with a high incidence of neuromuscular blocking agents without such monitoring. This suboptimal invasive, many anaesthetists continue to administer neuromuscular monitoring being risk free and entirely non-invasive, many anaesthetists continue to administer neuromuscular blocking agents without such monitoring. This suboptimal practice is associated with a high incidence (40%) of at least mild postoperative weakness among surgical patients admitted to postoperative recovery areas. By providing a model enriched for severe postoperative weakness, Thomsen and colleagues force us to consider that many of our patients with postoperative weakness are likely to be experiencing distressing awareness on awakening, even if they do not remember such experiences. Likewise, many patients are likely to suffer preventable respiratory complications.

There are three possible mechanisms of protection with neuromuscular monitoring: (i) prevention of premature wakening; (ii) restriction of pharmacological neuromuscular blocking agent administration; and (iii) appropriate dosing of antagonist medication. It is now well established that the sensation of paralysis is a key contributor to intraoperative awareness and the distress associated with awareness. It therefore comes as no surprise that the sensation of paralysis after completion of the surgery is a cause of mental anguish, from which we must protect our patients. The most parsimonious approach to avoidance of distressing intraoperative or postoperative awareness is to limit or preferably avoid the administration of neuromuscular blocking agents (see Fig. 1). These drugs continue to enjoy gratuitous administration, possibly on the basis of perceived convenience rather than on the basis of surgical necessity. For example, to immobilize the heart potassium is required, whereas non-depolarizing neuromuscular blocking agents (fortunately) are not cardiopleic. Nevertheless, the majority of patients undergoing open cardiac procedures are subjected to pharmacological paralysis of all their skeletal muscles. We are gaining experience with a repertoire of invasive procedures where patients receive no neuromuscular blocking agents; examples include major spine surgeries, where patients are in the prone position for prolonged periods, and other invasive procedures, with the head fixed in a Mayfield frame.

When neuromuscular blocking agents are needed to facilitate surgery, it is important not to administer the competitive antagonist neostigmine before the return of four visible twitches in a train of four on a peripheral nerve stimulator in order to succeed reliably in reversing the pharmacologically induced weakness. Neostigmine has a ceiling effect and will not prevent weakness if administered when a neuromuscular block is still profound, as revealed by a train-of-four ratio <0.4 at the adductor pollicis muscle following ulnar nerve stimulation. Furthermore, neostigmine should be administered ~20 min before planned tracheal extubation to allow time for peak drug effect (see Fig. 1). It is worth emphasizing that not all forms of neuromuscular monitoring are equal in terms of their reliability. With qualitative assessment (i.e. visual inspection or palpation), we are unable to distinguish between train-of-four ratios of 1 and 0.4. Quantitative monitoring (e.g. acceleromyography, mechanomyography,
kinemyography, and electromyography) is reliable in excluding residual weakness after non-depolarizing or depolarizing neuromuscular blocking agents, if a baseline was established before succinylcholine administration.6 15 16 Given that inhibitors of acetylcholinesterase (the enzyme that hydrolyses the neurotransmitter acetylcholine) can independently cause weakness through excessive cholinergic stimulation, a mismatch in dosing between neuromuscular blocking agents and the intended antagonist can result in weakness. Even the administration of a chemical antagonist of steroid neuromuscular blocking agents (i.e. sugammadex) might not prevent post-operative weakness.17 When sugammadex is administered without neuromuscular monitoring, ~10% of patients still have a train-of-four ratio <0.9.17

A principle governing anaesthetic practice should be that if an inexpensive and non-invasive monitor is available for a physiological system that is pharmacologically perturbed, consideration should be given to incorporating such a monitor into routine clinical practice. Organ systems to which this principle could reasonably apply include the cardiovascular system (blood pressure, heart rate, and electrocardiogram); the respiratory system (respiratory rate, tidal volume, oximetry, and capnography); the thermoregulatory system (temperature); the central nervous system (electroencephalography); and the neuromuscular system (neuromuscular monitoring). It is ironic that the very targets that are directly affected by anaesthetic and neuromuscular blocking agents (i.e. the brain and the neuromuscular junction) are the very organs that are currently not monitored routinely during general anaesthesia. Unlike the data pertaining to the monitoring of any other organ system, the data are by now compelling that withholding neuromuscular monitoring from our patients is associated with morbidity and distress.5 14 For regulatory organizations, it is time to get off the fence and to mandate neuromuscular monitoring as the standard of care whenever depolarizing and non-depolarizing neuromuscular blocking agents are administered in the operating theatre or in the intensive care unit (see Fig. 1). When our patients wake up weak and struggling for breath, the experience could feel like being pinned in the cocoon of a diving bell, deprived of oxygen, and able to register discomfort only with desperate, twitching gestures. We, the anaesthetists must learn from the harsh experiences of patients with atypical BChE and apply uniform principles in our practice to ensure that our patients always emerge from general anaesthesia like unencumbered butterflies.

Declaration of interest
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