Editorial

Progress towards a standard of quantitative twitch monitoring

A. Bowdle[1] and **S. Jelacic**[2]

1 Professor, 2 Associate Professor, Department of Anaesthesiology, University of Washington, Seattle, Washington, USA

Correspondence to: A. Bowdle
Email: bowdle@u.washington.edu
Accepted: 19 January 2020
Keywords: electromyography; mechanomyography; neuromuscular blockade; NMB reversal: acceleromyography assessment
This editorial accompanies an article by Thomsen et al., *Anaesthesia* 2020; https://doi.org/10.1111/anae.15083.
Twitter: @GaviaLabs

Thomsen et al. have performed a fascinating retrospective investigation of recent practices with monitoring and reversal of neuromuscular blocking drugs in six hospitals in Denmark [1]. Between 2014 and 2016, they recorded over 76,000 cases. From this large sample, they identified 16,525 cases where non-depolarising neuromuscular blocking drugs were used, either alone or in combination with succinylcholine. Eighty-eight percent (14,463) of the patients who received non-depolarising neuromuscular blocking drugs were monitored with the Philips NMT (Philips Healthcare, Amsterdam, The Netherlands) acceleromyograph quantitative twitch monitors.

We are strongly in favour of routine twitch monitoring as a standard of care. There is a lot of evidence supporting the routine use of quantitative twitch monitoring as 'best practice' [2]. Furthermore, quantitative twitch monitoring is urged by the Association of Anaesthetists [3]. Implementation of 'best practice' is daunting, as anyone who has ever been tasked with this in their organisation will attest [4]. The high rate of application of quantitative twitch monitoring in the studied hospitals is very impressive, and in our opinion the anaesthetists of these hospitals can be proud of their performance; they have set a high bar for the rest of us.

There are a number of other aspects of the report by Thomsen et al. that are worth considering. Electromyography and acceleromyography are the techniques used most often for quantitative twitch monitoring in the clinical setting. Mechanomyography is the gold standard for laboratory investigation of twitch monitoring but is not often used for clinical monitoring [5–7]. Acceleromyography requires that the thumb moves freely which prevents the use of acceleromyography in procedures where the patient's arms are tucked into blankets or surgical drapes. This constraint would apply to the Philips NMT acceleromyograph used by all of the hospitals in the study. This important limitation of acceleromyography is not mentioned by Thomsen's et al., but may account for some of the 12% of patients who received non-depolarising neuromuscular blockers but were not monitored. Acceleromyography has another important idiosyncrasy. Baseline (before neuromuscular blocking drug) train-of-four (TOF) ratio with acceleromyography is frequently > 1.0, and ranges up to about 1.4, possibly because the thumb does not return to the starting position during a TOF [8]. A TOF ratio much > 1.0 is generally not seen with electromyography or mechanomyography. Baseline TOF ratio > 1.0 has been documented previously for TOF-Watch (Organon, Ireland) [9], StimPod (Xvant Technology, South Africa) [9] and TOF Scan (Drager Technologies, Canada) [10] acceleromyography monitors. The Philips NMT acceleromyograph has not been well studied previously. Thomsen et al. have demonstrated that the Philips NMT monitor also has this idiosyncrasy. As shown in Fig. 3 of their paper, half of the TOF values recorded just before tracheal

extubation were between 1.0 and 1.6. Since many of the patients have some degree of residual neuromuscular blockade, true baseline TOF ratio is probably > 1.0 in more than half of patients when using the Philips NMT. Several investigators have recommended 'normalising' TOF values when using acceleromyography [9, 11, 12], and using a normalised TOF ratio of 0.9 as the criteria for recovery from neuromuscular blockade. This means that the TOF ratio should be divided by the baseline TOF ratio. For example, if the baseline TOF is 1.4 and the TOF ratio is 1.3 following antagonism of neuromuscular blockade, the normalised TOF ratio is 1.3/1.4 = 0.9. If we do not have a baseline TOF ratio, we probably should not assume that a raw TOF ratio value of 0.9 represents recovery from neuromuscular blockade. A patient with a baseline TOF ratio of 1.4 will need to have a TOF ratio of 1.3 in order to have a normalised TOF ratio of 0.9. In the same patient, a raw TOF ratio value of 0.9 would equate to a normalised TOF ratio of only 0.6. Thomsen et al. reported that 22% of the patients who received non-depolarising neuromuscular blocking drugs had residual neuromuscular blockade, as judged from a TOF ratio at the time of tracheal extubation of < 0.9. Since the TOF values were not known to be normalised, in all likelihood there were many more than 22% of patients with residual neuromuscular blockade.

Electromyography has the advantage of not requiring that the thumb move, since muscle action potentials are measured directly. The baseline TOF is seldom > 1.0, eliminating the need for normalisation. Although electromyography is not a new technology, it has not been available widely for clinical use until recently. There are now two commercially available stand-alone electromyograph monitors: the TwitchView Monitor (Blink Device Company, Seattle, USA) and; the Tetragraph (Senzime AB, Uppsala, Sweden). We have validated the TwitchView Monitor against mechanomyography [13]. There is also a GE Healthcare (E-NMT-01, GE Healthcare, USA) electromyograph that requires the use of the GE monitoring system. The Tetragraph and GE electromyograph have not been validated against mechanomyography to the best of our knowledge.

What about Thomsen et al.'s data for antagonism of neuromuscular blockade? Fifty-two percent of patients who received non-depolarising neuromuscular blocking drugs received neostigmine for reversal and 1% received sugammadex; the remainder received no agent. At the time neostigmine was administered, the TOF count was 0–1 (there were no post-tetanic count data available) in 9% and 2–4 (but a TOF ratio of zero) in 30%. Neostigmine is only a reliable antagonist in patients with shallow neuromuscular blockade. For neostigmine to be reliably effective, there should be four twitches, and probably a minimal TOF ratio > 0.2 at the time neostigmine is administered [14]. Thus, we would predict that many patients in the study who received neostigmine would have residual neuromuscular blockade afterwards. Avoiding residual neuromuscular blockade in these patients would have required administering an effective dose of sugammadex or waiting longer for the neuromuscular blocking effects to wear off before tracheal extubation.

Simply having a quantitative twitch monitor does not by itself prevent residual neuromuscular blockade. The monitor has to be used properly and the pharmacology of the neuromuscular blocking drugs and antagonist agents has to be understood. We are not surprised that there is room for improvement even in Denmark, despite its advanced attention to quantitative twitch monitoring. Improvement requires measuring performance, as Thomsen et al. have done; identifying problems (in this case, residual neuromuscular blockade); devising solutions (e.g. normalising TOF ratio data, making sure patients have a normalised TOF ratio of ≥ 0.9 before tracheal extubation, understanding the limitations of neostigmine as an antagonist agent); and repeating the measurements. Thomsen et al. are ideally positioned to carry out this important quality improvement work.

Thomsen et al. were not able to measure patient respiratory outcomes, except for oxygen saturation immediately following tracheal extubation. It would have been interesting to determine whether the specific patients with residual neuromuscular blockade, defined as a TOF ratio at tracheal extubation < 0.9 (realising that without normalisation, the true incidence of residual neuromuscular blockade will be underestimated) had lower oxygen saturation than patients without residual neuromuscular blockade. This comparison was not made. In our opinion, the fact that twitch monitoring per se did not appear to effect oxygen saturation in a logistic regression analysis, does not mean much. As previously stated, having the monitor does not by itself prevent residual neuromuscular blockade.

Finally, Thomsen et al. have proposed that we should routinely perform twitch monitoring in patients who receive only succinylcholine, in order to detect residual neuromuscular blockade due to pseudocholinesterase deficiency. This is a provocative suggestion. Pseudocholinesterase deficiency is seldom considered in discussions of residual neuromuscular blockade, which tend to focus on non-depolarising neuromuscular blocking drugs, and most providers probably do not currently utilise twitch monitoring when succinylcholine is administered for tracheal intubation. Indeed, monitoring

succinylcholine blockade seems to us a reasonable proposal. Incidentally, it turns out that succinylcholine causes fade in the TOF stimulation responses after normal doses for tracheal intubation, despite the popular notion that succinylcholine only causes diminution of twitch height, but not fade [15, 16].

In conclusion, we urge the use of routine quantitative twitch monitoring. Although electromyography has a number of advantages, acceleromyography can be used effectively especially when a baseline TOF ratio can be obtained before administration of the neuromuscular blocking drug, allowing for normalisation of subsequent TOF measurements. The trachea should not be extubated until the TOF ratio reaches a normalised value of at least 0.9. The widespread adoption of quantitative twitch monitoring could be enhanced by the increased participation of professional societies and by the availability of more reliable and user-friendly twitch monitors, which should be validated by comparison with mechanomyography.

Acknowledgements

No competing interests declared.

References

1. Thomsen JLD, Staehr-Rye AK, Mathiesen O. Hägi-Pedersen D, Gätke MR. Neuromuscular monitoring practice: a study of anaesthesia data from 30.430 patient cases at six Danish hospitals. *Anaesthesia* 2020; in press.
2. Brull SJ, Kopman AF. Current status of neuromuscular reversal and monitoring: challenges and opportunities. *Anesthesiology* 2017; **126**: 173–90.
3. Checketts MR, Alladi R, Ferguson K, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015: Association of Anaesthetists. *Anaesthesia* 2016; **71**: 85–93.
4. Todd MM, Hindman BJ, King BJ. The implementation of quantitative electromyographic neuromuscular monitoring in an academic anesthesia department. *Anesthesia and Analgesia* 2014; **119**: 323–31.
5. Fuchs-Buder T, Claudius C, Skovgaard LT, et al. Good clinical research practice in pharmacodynamic studies of neuromuscular blocking agents II: the Stockholm revision. *Acta Anaesthesiogical Scandinavica* 2007; **51**: 789–808.
6. Eriksson LI, Sundman E, Olsson R, et al. Functional assessment of the pharynx at rest and during swallowing in partially paralyzed humans: simultaneous videomanometry and mechanomyography of awake human volunteers. *Anesthesiology* 1997; **87**: 1035–43.
7. Berg H, Roed J, Viby-Mogensen J, et al. Residual neuromuscular block is a risk factor for postoperative pulmonary complications. A prospective, randomised, and blinded study of postoperative pulmonary complications after atracurium, vecuronium and pancuronium. *Acta Anaesthesiologica Scandinavica* 1997; **41**: 1095–103.
8. Brull SJ, Silverman DG. Real time versus slow-motion train-of-four monitoring: a theory to explain the inaccuracy of visual assessment. *Anesthesia and Analgesia* 1995; **80**: 548–51.
9. Liang SS, Stewart PA, Phillips S. An ipsilateral comparison of acceleromyography and electromyography during recovery from nondepolarizing neuromuscular block under general anesthesia in humans. *Anesthesia and Analgesia* 2013; **117**: 373–9.
10. Murphy GS, Szokol JW, Avram MJ, et al. Comparison of the TOFscan and the TOF-Watch SX during recovery of neuromuscular function. *Anesthesiology* 2018; **129**: 880–8.
11. Kopman AF. Normalization of the acceleromyographic train-of-four fade ratio. *Acta Anaesthesiologica Scandinavica* 2005; **49**: 1575–6.
12. Capron F, Alla F, Hottier C, Meistelman C, Fuchs-Buder T. Can acceleromyography detect low levels of residual paralysis? A probability approach to detect a mechanomyographic train-of-four ratio of 0.9. *Anesthesiology* 2004; **100**: 1119–24.
13. Bowdle A, Bussey L, Michaelsen K, et al. A comparison of a prototype electromyograph vs. a mechanomyograph and an acceleromyograph for assessment of neuromuscular blockade. *Anaesthesia* 2020; **75**: 187–95.
14. Kaufhold N, Schaller SJ, Stauble CG, et al. Sugammadex and neostigmine dose-finding study for reversal of residual neuromuscular block at a train-of-four ratio of 0.2 (SUNDRO20). *British Journal of Anaesthesia* 2016; **116**: 233–40.
15. Naguib M, Lien CA, Aker J, Eliazo R. Posttetanic potentiation and fade in the response to tetanic and train-of-four stimulation during succinylcholine-induced block. *Anesthesia and Analgesia* 2004; **98**: 1686–91.
16. De Jong RH, Freund FG. Characteristics of the neuromuscular block with succinylcholine and decamethonium in man. *Anesthesiology* 1967; **28**: 583–91.

