

CORRESPONDENCE

Automatic, targeted, and unobtrusive intraoperative reminders to improve neuromuscular transmission monitoring: a retrospective cohort study

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Editor—In 2023, both the American Society of Anesthesiologists¹ and the European Society of Anaesthesiology and Intensive Care² published guidelines concerning the management of neuromuscular block. Both recommend quantitative neuromuscular transmission (NMT) monitoring at the adductor pollicis muscle when neuromuscular blocking agents (NMBAs) are used to minimise the risks associated with residual neuromuscular block. We previously reported data on the frequency of NMT monitoring in patients receiving NMBAs in our institution (Radboud University Medical Centre), a large tertiary teaching hospital in the Netherlands. The documented use of NMT monitoring increased from 47% (2015–2017) to 64% (2018–2019) after introduction of integrated quantitative NMT monitors (Philips IntelliVue NMT module; Philips, Eindhoven, The Netherlands) in every operating room, with automatic data entry in the electronic health record (EHR).³ The rate of monitoring subsequently rose further to 77.6% in 2023–2024.⁴ In November 2024, we implemented an automated reminder within the anaesthesia module of our EHR system (Epic Systems Corporation, Verona, WI, USA) to improve the rate of NMT monitoring further. These rule-based alerts are called best practice advisories (BPAs) in Epic. This specific BPA utilises discrete timestamps from the anaesthesia record, case start (patient entry into the operating room), and surgery end (wound closure), which are always documented. It also assesses documented NMT data and administration of nondepolarising NMBAs using a medication grouper. If an NMBA is administered and no NMT

data have been recorded 45 min after start of the case, a clear yet unobtrusive reminder appears in the sidebar of the screen (Fig. 1). The same reminder is displayed a second time at the end of surgery if NMT data remain unrecorded. Our intention was to minimise the risk of alert fatigue by targeting only those patients in whom NMT monitoring appeared to have been overlooked, by using a 45-min delay and avoiding disruptive pop-up alerts. Chronic alarm fatigue has been associated with continued exposure to nonactionable alarms.⁵

To assess the effectiveness of this intervention, we conducted a retrospective analysis of 500 anaesthesia records from February and March 2025 starting 3 months after implementation. Inclusion criteria were adult patients undergoing general anaesthesia using a nondepolarising NMBA. Cardiothoracic and emergency surgeries were excluded. The sample size and inclusion and exclusion criteria were matched to those of our earlier study from 2023–2024, which examined residual neuromuscular block in the postanesthesia care unit.⁴ The medical research ethics committee METC Oost-Nederland confirmed that the study was outside the remit of the Dutch Medical Research Involving Human Subjects Act (WMO).

Quantitative NMT monitoring was performed in 92.6% of patients, representing a significant increase ($P < 0.001$) compared with the 77.6% recorded ~1 yr previously⁴ (χ^2 test conducted in Microsoft® Excel® for Microsoft 365 MSO, version 2402; Microsoft Corp., Redmond, WA, USA). Among the 37 patients without documented NMT measurements,

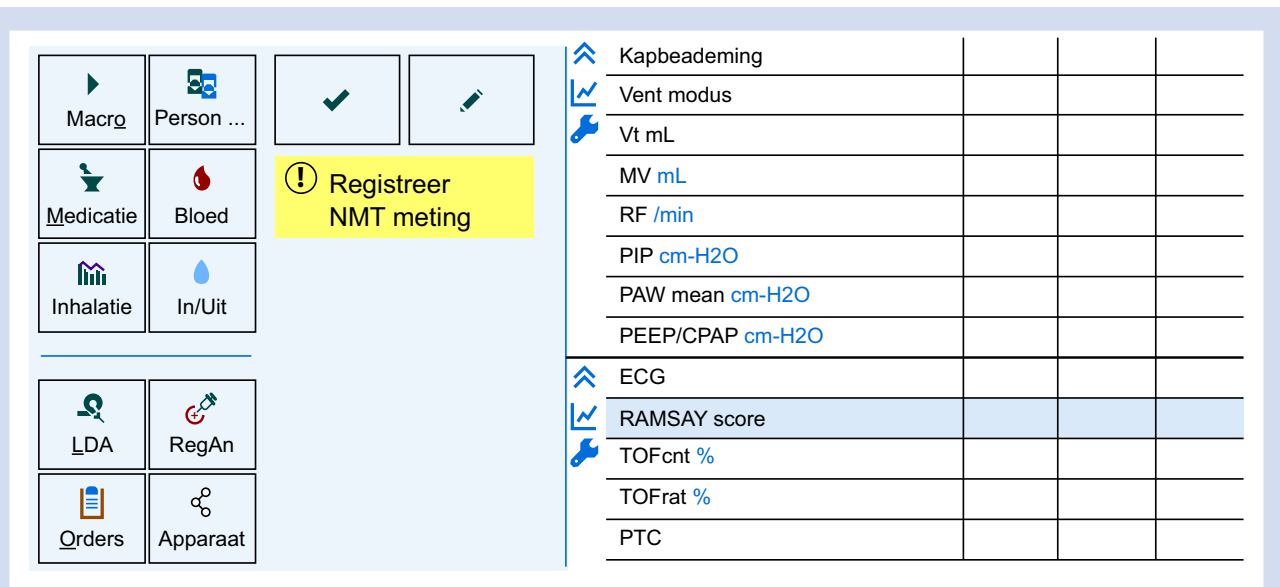


Fig 1. Reminder in the Epic electronic health record sidebar. The message in Dutch translates to 'document NMT measurement'.

sugammadex was administered in six patients, and five involved extensive surgery with planned postoperative mechanical ventilation and subsequent tracheal extubation in the intensive care unit.

The POPULAR trial⁶, which investigated postanaesthesia pulmonary complications after the use of NMBA in 22 803 patients across 211 hospitals in Europe during 2014 and 2015, showed use of any NMT monitoring in only 42.1% of patients receiving an NMBA. Increasing the use of NMT monitoring in clinical practice remains an ongoing challenge. Earlier studies^{7–9} showed varying effectiveness of educational modules, spaced education, and multifaceted interventions including equipment trials and decision support in promoting NMT monitoring. In contrast, our study specifically evaluated the isolated impact of automatic reminders. Intraoperative clinical decision support has been demonstrated to be effective in various contexts, including glucose control, timely antibiotic administration, indications for antiemetic therapy, and alerts regarding excessive fresh gas flow to reduce inhalation anaesthetic waste.¹⁰

The diffusion of innovation theory described by Rogers in 2003 states that a self-sustaining adoption trend is typically established once a tipping point of ~20% uptake is reached¹¹. Beyond this threshold, peer influence and social validation play a substantial role in accelerating further dissemination. As adoption progresses beyond 20% and approaches 50%, habit formation and integration into institutional workflows further reinforce and normalise practice. In anaesthesia, notable precedents include pulse oximetry and capnography, both of which progressed from limited use (5–10%) to near-universal adoption within a decade in the 1980s and 1990s. In those patients, clear clinical benefits, combined with strong professional consensus and regulatory mandates, facilitated transition from early adoption to routine practice. In contrast, although clinically usable quantitative NMT monitoring devices have been available since 1988,¹¹ widespread uptake has been hindered by practical limitations, evolving recognition of the clinical relevance of low levels of residual neuromuscular

block, delayed presentation of associated complications, and slow integration in professional guidelines. Nevertheless, NMT monitoring has passed the social tipping point for adoption in Europe, with a reported usage rate of 42.1% in 2015⁶. As of 2023, both European and American anaesthesia societies mandate its use in their guidelines^{1,2}, which is likely to accelerate integration further.

The diffusion of innovation theory of adoption trends¹² aligns with our local experience: once NMT monitoring reaches a critical level of adoption among anaesthesia personnel, it increasingly becomes routine clinical practice no longer requiring conscious effort to ensure consistent use. Discrete automated documentation of NMT measurements within the EHR enabled use of targeted reminders and synergistically reinforced adoption and consistent practice. Although automated NMT data entry is preferred, automatic reminders remain feasible even when handheld, nonintegrated NMT monitors are used, provided that monitoring data are entered into standardised discrete fields within the EHR.

Our data indicate a significant and encouraging improvement in NMT monitoring rates over the past decade. Automatic, targeted, and unobtrusive reminders appear to have contributed substantially to this progress. They are also likely to sustain continued vigilance, offering a long-term advantage over brief educational interventions alone.

Declaration of interest

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