

Notes in Medicine

Fuchs-Buder

Neuromuscular Monitoring in Clinical Practice and Research



Springer

Thomas Fuchs-Buder

**Neuromuscular monitoring in clinical practice
and research**

Thomas Fuchs-Buder

Neuromuscular monitoring in clinical practice and research

With 50 figures and 16 tables

 Springer

Professor Thomas Fuchs-Buder, M.D.

Department of Anesthesia and Critical Care

Centre Hospitalier Universitaire de Nancy/Brabois

54511 Vandœuvre-lès-Nancy, France

ISBN-13 978-3-642-13476-0 Springer Medizin Verlag Heidelberg

Bibliographic information published by the Deutsche Nationalbibliothek.

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at <http://dnb.d-nb.de>.

This work is subject to copyright laws. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broad-casting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965 in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

Springer Medizin

springer.com

ein Unternehmen von Springer Science+Business Media

© Springer-Verlag GmbH Heidelberg 2010

The use of general descriptive names, registered names, trademarks etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product liability: The publishers cannot guarantee the accuracy of any information about dosage or application contained in this book. In every individual case, the user must check all such information by consulting the pertinent literature.

Cover design: deblik Berlin, Germany

Production, reproduction and typesetting: TypoStudio Tobias Schaedla, Heidelberg, Germany

Copy editing of German version: Bettina Arndt, Gorchheimertal, Germany

English translation: Deborah A. Landry, B.A., Göttingen, Germany

Printers: ML - Media Consult, Mannheim, Germany

SPIN 12992713

Printed on acid-free paper

18/5135/DK – 5 4 3 2 1 0

Foreword

More than 25 years ago, at a time when neuromuscular function monitoring was only seldom used, it was documented that postoperative residual curarization (PORC), also referred to as residual paralysis, was frequent in three university hospitals in Copenhagen. The initial response of colleagues was that this finding most probably was due to insufficient training of anesthesiologists in Denmark and therefore did not apply to other departments in other parts of the world. Over the next years, it was documented that the high incidence of PORC was not solely a Danish problem: It was seen in other places of the world, when a neuromuscular block was not monitored and sufficient recovery of neuromuscular function was sought ensured using only clinical criteria, such as sustained eye opening, tongue protrusion or sustained head or arm lift. Soon it became apparent that the sole use of subjective evaluation of the response to peripheral nerve stimulation also did not exclude PORC and that the only reliable way to detect PORC was by the use of objective neuromuscular monitoring. This time the response among many anesthesiologists was that it might be true, but it did not matter, as PORC does not pose a threat to the patient. However, Professor Lars I. Eriksson and his group at Karolinska Hospital in Sweden showed that even moderate degrees of residual block decrease the chemoreceptor sensitivity to hypoxia. They also showed that PORC is associated with functional impairment of the muscles of the pharynx and upper esophagus, most probably leading to regurgitation and aspiration. Most recently, Dr. Eikermann and colleagues documented that partial neuromuscular block, even to a degree that does not evoke dyspnea or hypoxemia, may decrease inspiratory airway volume and can cause partial inspiratory airway collapse¹. In accordance with this, it has been documented that PORC is a significant risk factor for the development of postoperative pulmonary complications and may lead to increase morbidity and mortality^{2,3}. In spite of the above, many clinicians still do not monitor regularly. In USA it is still more the exception than

¹ Eikermann et al. *Am J Respir Crit Care Med.* 2007;175: 9–15.

² Berg H et al. *Acta Anaesthesiol Scand.* 1997;41:1095–1103.

³ Murphy GS et al. *Anesth Analg.* 2008;107:130–137.

the rule that the anesthesiologists use a nerve stimulator. In UK 60% state that they never or seldom use a nerve stimulator and only 9-10% monitor neuromuscular function routinely.⁴ Somewhat better is the situation in Denmark and Germany, where recent surveys have shown that 40-45% of all anesthesiologists use a nerve stimulator regularly. Personally, I support the notion recently expressed in an editorial in *Anesthesiology* that objective monitoring is an evidence-based practice that should consequently be used whenever a neuromuscular blocking drug is administered. I hope that this book will convince the skeptics by spreading the above message. At least the editor has done his share. I wish the book all the best of luck.

Jørgen Viby-Mogensen

⁴ Grayling M, Sweeney BP. Recovery from neuromuscular blockade: a survey of practice. *Anaesthesia*. 2007 Aug;62(8):806–809

Preface

Compared to their precursors, the current generation of neuromuscular blocking agents features improved controllability. This improvement was accomplished by optimizing the metabolic pathways where, now, no more pharmacologically active metabolites are formed as well as by achieving more reliable elimination, even in patients whose organ function is limited. These properties have made it possible to reduce the risk of cumulative effects, particularly after repeated doses of relaxant.

Notwithstanding these improvements, the pharmacodynamic action of today's neuromuscular blocking agents is still subject to pronounced individual variations. Both the onset and duration of action as well as neuromuscular recovery have only limited predictability in the individual patient. Moreover, the action of neuromuscular blocking agents is influenced by numerous external factors such as concomitant diseases, drug interactions and pharmacogenetic factors. In particular, the incidence of residual neuromuscular blockade – a proven risk factor for severe postoperative complications – continues to be unacceptably high.

Even the most clinically relevant residual blockade is often imperceptible to anesthesiologists if they have to rely on their mere senses, and can generally only be made visible by neuromuscular monitoring. Thus, the willingness to reverse is also accordingly heightened. So, it is not surprising that the preclusion to monitor neuromuscular function counts as a critical, independent risk factor for the occurrence of postoperative residual blockades.

While its benefits remain uncontested, the use of neuromuscular monitoring in clinical practice often lags behind expectations.

The present textbook contains information that is essential for the judicious application of neuromuscular monitoring and also discusses the merits of neuromuscular monitoring in clinical settings. Special importance has been placed on a comprehensive presentation of acceleromyography.

Table of Contents

1	Principles of neuromuscular transmission	1
1.1	Physiological principles	2
1.1.1	Anatomical principles	2
1.1.2	Action potential	4
1.1.3	Acetylcholine	5
1.1.4	Postsynaptic nicotinic acetylcholine receptors	7
1.1.5	Presynaptic nicotinic acetylcholine receptors	9
1.1.6	Striated muscles	10
1.2	Pharmacological principles	11
1.2.1	Non-depolarizing neuromuscular blocking agents	11
1.2.2	Depolarizing neuromuscular blocking agents	15
1.2.3	Cholinesterase inhibitors	16
1.2.4	Selective relaxant binding agents drugs	19
	References	22
2	Principles of neuromuscular monitoring	23
2.1	Nerve stimulation	24
2.2	Stimulation electrodes	26
2.3	Stimulation site/test muscle	30
2.3.1	Ulnar nerve/adductor pollicis muscle	31
2.3.2	Posterior tibial nerve/flexor hallucis brevis muscle	32
2.3.3	Facial nerve/orbicularis oculi muscle or facial nerve/corrugator supercillii muscle	33
2.4	Anesthesia-relevant muscle groups	37
2.4.1	Diaphragm	38
2.4.2	Laryngeal muscles	39
2.4.3	Abdominal muscles	39
2.4.4	Extrinsic muscles of the tongue and floor of mouth	40
2.4.5	Pharyngeal muscles	40
2.5	Stimulation patterns	41
2.5.1	Single twitch	42
2.5.2	Train-of-four	43
2.5.3	Double-burst stimulation	49

2.5.4	Tetanic stimulation.....	51
2.5.5	Post-tetanic count	53
2.6	Assessment of stimulatory response.....	56
2.6.1	Simple nerve stimulators.....	56
2.6.2	Quantitative nerve stimulators	59
	References.....	70
3	Clinical application.....	73
3.1	Neuromuscular monitoring during anesthesia induction.....	76
3.1.1	Neuromuscular blocking agents for anesthesia induction?	77
3.1.2	Test muscles and stimulation patterns.....	82
3.1.3	What level of neuromuscular block for intubation?.....	87
3.2	Intraoperative application of neuromuscular monitoring.....	90
3.2.1	Accumulation of NMBAs	91
3.2.2	Stimulation patterns and test muscles.....	95
3.3	Monitoring neuromuscular recovery.....	97
3.3.1	Pathophysiological implications of residual neuromuscular blockade	98
3.3.2	Frequency of residual neuromuscular blockade.....	106
3.3.3	Clinical implications associated with residual neuromuscular blockade	108
3.3.4	Stimulation patterns and test muscle.....	110
3.3.5	Prevention strategies for residual neuromuscular blockade.....	114
	References.....	120
4	Acceleromyography.....	124
4.1	Principles.....	126
4.2	The Accelograph and the TOF-Guard	127
4.3	TOF-Watch® models.....	130
4.3.1	The TOF ratio algorithm	130
4.3.2	Calibration modes	133
4.3.3	Nerve localization in regional anesthesia procedures.....	136
4.4	TOF-Watch®.....	138
4.4.1	Short set-up instructions.....	138
4.4.2	Brief overview	139
4.4.3	Scheme of buttons and display symbols.....	140
4.5	TOF-Watch® S.....	150

4.5.1	Short set-up instructions	150
4.5.2	Brief overview	151
4.5.3	Scheme of buttons and display symbols	152
4.6	TOF-Watch® SX	164
4.6.1	Short set-up instructions	164
4.6.2	Brief overview	165
4.6.3	Scheme of buttons and display symbols	166
4.6.4	Scheme of buttons and display symbols	168
4.7	FAQS	179
4.7.1	Can acceleromyography also be used in infants?	179
4.7.2	Is neuromuscular monitoring painful for patients?	180
4.7.3	What to observe when attaching TOF-Watch® nerve stimulators?	182
4.7.4	Is calibration really necessary?	184
4.7.5	Can neuromuscular monitoring with the TOF-Watch® nerve stimulator prevent residual blockade?	190
4.8	Acceleromyography in research	193
4.8.1	Neuromuscular monitoring for scientific purposes: What should anesthesiologists generally look out for?	194
4.8.2	Particulars of performing acceleromyography	197
4.8.3	Guidelines for measuring onset and time profile of neuromuscular blockade	198
	Concluding remarks	200
	References	202
	Subject Index	205

