Monitoring techniques; neuromuscular blockade and depth of anaesthesia

Alexander S Wycherley

Jane L Bembridge

Abstract

This article outlines the physical principles underlying peripheral nerve stimulation and depth of anaesthesia monitoring in relation to anaesthesia. The patterns of nerve stimulation most commonly used in clinical practice are described including train-of-four, double burst stimulation and tetanic stimulation, as well as methods used to measure motor response. The key technologies currently used to monitor level of consciousness during anaesthesia are also described, namely methods based on electroencephalography and stimulus evoked potentials, including limitations of their use. Published clinical guidelines on the use of both nerve stimulators and level of consciousness monitors are also discussed.

Keywords Awareness; bispectral index; depth of anaesthesia; monitoring; neuromuscular blockade; train-of-four

Royal College of Anaesthetists CPD matrix: 1A03, 2A04

Learning objectives

After reading this article, you should be able to:

- discuss the different patterns of nerve stimulation for neuromuscular monitoring
- explain the operation of a range of depth of anaesthesia monitors
- relate the use of neuromuscular and depth of anaesthesia monitoring to current guidelines

A range of technologies exist to allow monitoring of the peripheral and central nervous systems during anaesthesia. Knowledge of the physical principles underlying these technologies is essential to ensure correct use and avoid complications.

Neuromuscular monitoring

Neuromuscular monitoring is essential during all phases of anaesthesia, especially during recovery from neuromuscular blockade (NMB). The Difficult Airway Society (DAS) recommends the routine use of peripheral nerve stimulators to confirm reversal of NMB prior to extubation.[1] A number of clinical techniques may be used to assess reversal of NMB, including the ability to protrude the tongue, lift the head for 5 seconds or deliver a vital capacity breath. These methods are prone to influence from factors such as residual sedation and patient compliance. Guidelines on the *Recommended Standards of Monitoring* from the Association of Anaesthetists of Great Britain and Ireland (AAGBI) state that whenever muscle relaxants are used, a nerve stimulator must be available during induction, maintenance and recovery from anaesthesia.[2] Despite this, a 2007 survey showed that less than 10% of UK anaesthetists routinely use nerve stimulators.[3]

***Alexander S Wycherley** BSc MBChB FRCA is a Senior Anaesthetics Registrar at Leeds Teaching Hospitals, UK. Conflicts of interest: none declared.*

***Jane L Bembridge** MBCh BFRCA is a Consultant Anaesthetist at Bradford Royal Infirmary, UK. Conflicts of interest: none declared.*

Nerve stimulators

The use of a nerve stimulator to determine residual NMB was first described by Christie and Churchill-Davidson in 1958.[4] A nerve stimulator is a battery powered hand-held device able to generate and deliver an electrical DC current. Current is typically delivered transcutaneously using standard silver/silver chloride ECG electrodes. Skin should be cleaned prior to the application of electrodes to reduce electrical impedance. The negative (black) cathode is placed over a distal point of the nerve, and the positive (red) anode is placed proximally.

The diaphragm is relatively resistant to NMB. During induction and maintenance of anaesthesia, it is preferable to monitor a similarly resistant muscle to ensure adequate relaxation, such as the orbicularis oculi above the eye (innervated by the facial nerve). During recovery, monitoring of a more sensitive muscle, such as the adductor pollicis of the thumb (ulnar nerve), is preferable to confirm full return of muscle power. Other sites used for monitoring include the common peroneal nerve at the fibular head (causing ankle dorsiflexion) and the posterior tibial nerve at the ankle (causing ankle plantar flexion). The maximal stimulus is the current required to stimulate all nerve fibres in a given nerve, and is typically 50 mA; however, this varies inversely with impedance (typically 0–5 kΩ), which is determined by: electrical contact, tissue thickness, hair, moisture, and temperature. Most nerve stimulators deliver a supramaximal stimulus that is $\geq$125% maximal stimulus. A number of different patterns of stimulation can be used.

Patterns of nerve stimulation

Single twitch: a single square wave is applied for 0.2 ms. This can be delivered at repeated intervals, such as every second (1 Hz). Its use is limited by the need for a control twitch as a reference before the administration of a neuromuscular blocking agent.

Train-of-four: the train-of-four (TOF) pattern was developed by Ali et al. in 1970 as a clinical tool for the assessment of NMB (Figure 1).[5] TOF is especially useful when assessing the effects of non-depolarizing drugs due to the phenomenon of fade, which occurs due to depletion of pre-synaptic stores of acetylcholine. Increasing non-depolarizing block causes twitch height to reduce in a sequential manner, with T4 (the 4th twitch) disappearing first and T1 last. The number of twitches seen is known as the TOF count (Table 1). During recovery, T1 reappears first and T4 last. At the reappearance of T3, reversal agents may be safely given to antagonize non-depolarising agents. The TOF ratio

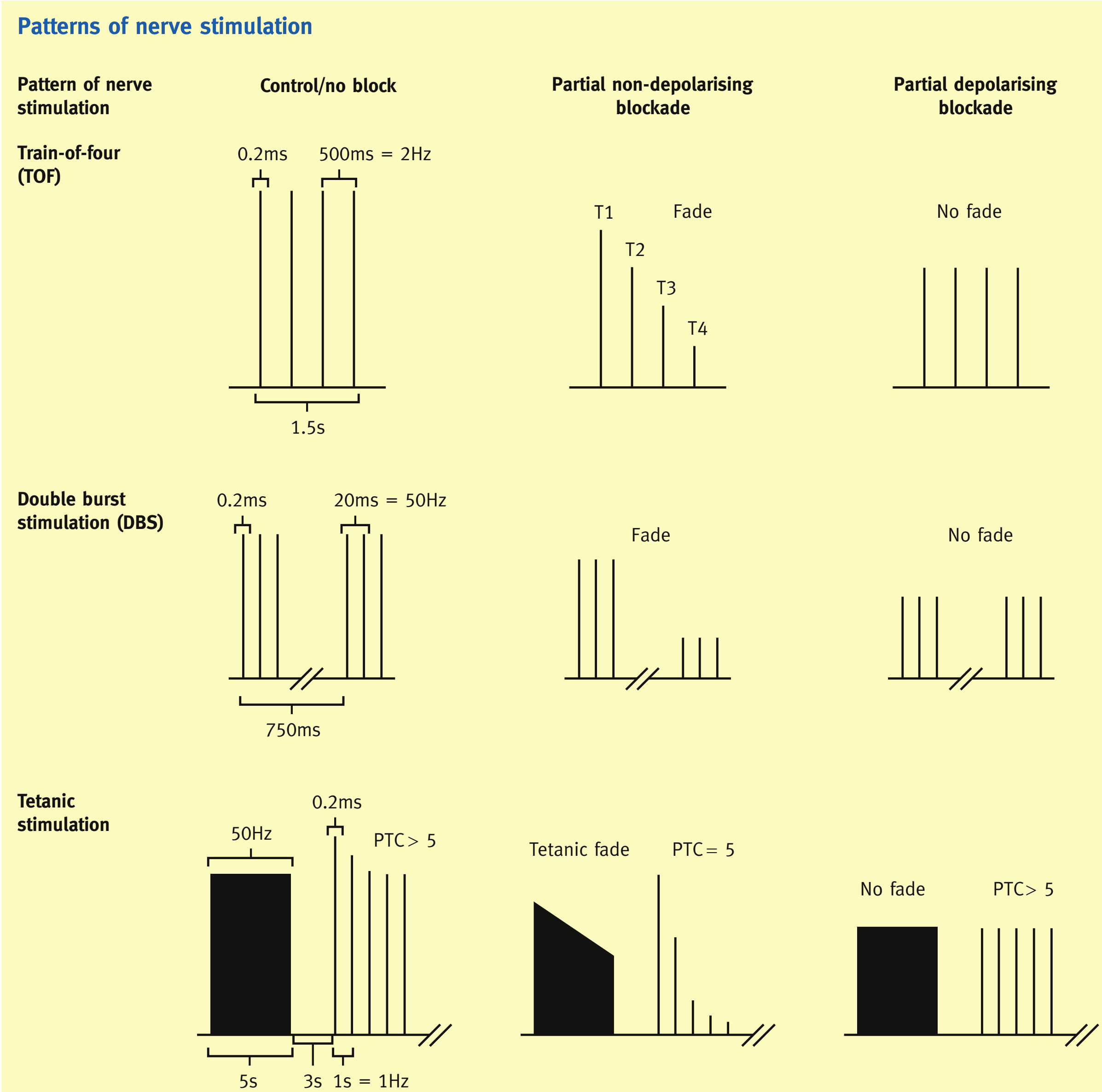

Figure 1

describes the difference in twitch height between T4 and T1. Following the work of Ali et al., a TOF ratio of 0.7 was previously accepted as demonstrating an adequate level of reversal; however, recent guidelines from DAS recommend a TOF ratio of 0.9 or above prior to extubation.[1]

Train-of-four count

Train-of-four count	Twitches present	Number of acetylcholine receptors blocked
0	None	100%
1	T1	90%
2	T1, T2	80%
3	T1, T2, T3	75%
4	All	<75%

Table 1

TOF is less useful in determining a partial depolarizing block. Depolarizing blocks do not exhibit fade, so each twitch is reduced equally. If large or repeated doses of depolarizing agent are given, a phase-II block may develop which exhibits many characteristics of a non-depolarizing block.

Tetanic stimulation: where NMB is profound, high-frequency stimulation can be used to induce tetanic muscular contraction. Tetany mobilizes additional acetylcholine from the pre-synaptic nerve terminal and increases intracellular calcium levels, exaggerating the response to subsequent stimuli. Where TOF would fail to elicit a response, single twitches that follow tetanic stimulation may elicit a response. This is known as post-tetanic potentiation (PTP). The post-tetanic count (PTC) is the number of twitches seen after tetanic stimulation (Figure 1). The PTC is inversely related to the time before reappearance of T1 of TOF, and is specific to individual anaesthetic agents. A tetanic

