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Hysteresis Loop Can be an Adjunct Monitoring for Neuromuscular Blockade while on Controlled Ventilation During Low- and Minimal-Flow Anaesthesia

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Dear Editor,

The respiratory mechanics is different during spontaneous, assisted and controlled ventilation, and this is reflected in the ventilator graphics. The pressure-volume hysteresis loop is one of many such graphics, and its abnormalities can occur with an inadequately sensitive trigger and alterations in respiratory compliance, thus indicating the patient-ventilator asynchrony (1). Although the uses of ventilator graphics are very common in the management of critically ill mechanically ventilated patients and have been shown to play an important role in patient management, their use in the operating room is not known well or frequently reported.

Neuromuscular wear-off and the appearance of a notch in the capnography known as the curare cleft are very well-known, time-tested findings used by anaesthesiologists when deciding on the MR supplement. The curare cleft results from the brief inspiratory effort of the patient occurring during expiration, leading to a transient decrease in CO2 during the plateau phase (2). This cleft in the capnogram indicates muscle paralysis as partial. However, the curare cleft is not devoid of limitations, and artefacts can also lead to a curare cleft-like feature (3, 4). Moreover, the time capnogram itself has some limitations, and the beginning and the end of an inspiratory segment cannot be delineated accurately without superimposing the simultaneously recorded respiratory flows (5).

While conducting the low-flow anaesthesia with an fresh gas flow (FGF) of 600 mL min-1 and minimal-flow anaesthesia with an FGF of 500 mL min^{-1}, it was observed that the pressure-volume loop gave a typical finding when the neuromuscular blockade started wearing off to the clinical inadequate level, as evident and defined by the train-of-four (TOF) Count 2 or more. A negative deflection (in the pressure axis) in the hysteresis loop was observed to coincide or just precede the curare cleft, and it was found to correspond to mostly two twitches in the TOF monitoring. As time progressed, and if muscle relaxant (MR) was not supplemented, a minor satellite expiratory flow deflection in the flow-time scalar and scalloping in the inspiratory limb of the hysteresis loop was also observed (Figure 1). The spirometry changes became more prominent with passing time, and corresponding increasing depth in the curare cleft was also observed. The negative deflection was not associated with the volume change in the early phase, but a minor volume change was also evident as time progressed in the hysteresis loop. All these features were reversed to normal with MR supplementation. The observation was done in a total of 4 patients (undergoing both bone forearm surgery in a poly-trauma patient, one breast lump surgery, one craniotomy, and one lumbar spine surgery), aged 18-72 years, and the negative deflection in the pressure-volume hysteresis loop was found to be the consistent earliest feature. The anaesthesia was provided using the A7 anaesthesia workstation with an attached BeneView T8 multiparameter patient monitor (Mindray Medical International Limited, Shenzhen, China), with positive-pressure

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Figure 1. Relationship of the train-of-four, capnogram and ventilator graphics with an illustration of the features in the ventilator graphics
A: Negative deflection; B: Scalloping; C: sattelite expiratory flow time scaller

ventilation from bellows in the volume-controlled mode with vecuronium as an MR.

Low- and minimal-flow anaesthesia needs special attention, and it is not possible to increase the depth of anaesthesia rapidly only by increasing the dial settings of the vaporiser without increasing the flow. Some of the surgical procedures need extra care with the neuromuscular blockade where a deeper level of blockade is desired. A curare cleft-based supplement is not perfect, and the use of the neuromuscular block testing such as TOF is advocated during per operative time due to different advantages (6). Unfortunately, this is not available in many places. Moreover, the TOF monitoring is usually not continuous, and it is possible that the subclinical level of the neuromuscular blockade may fall in the time gap of TOF monitoring. As the ventilator is very much an integral part of the modern-day anaesthesia machine, even in relatively lower-end versions, and graphics are available with in-built software, this finding can help the anaesthesiologists in making a better decision. The spirometry is continuous and real time as well. Therefore, this can be an adjunct of both the curare cleft and TOF monitoring. The clinical application of this feature as monitoring may even help in differentiating other curare-cleft-mimicking events, aid in deciding a top-up dose where the deep blockade is required, reversal of neuromuscular blockade and even when EtCO2 is temporarily not functioning properly. However, it was also observed that the ventilator graphics were sensitive to thoracic movements, and some surgical procedures may affect this too. Therefore, a prospective observation will be required in a greater number of cases undergoing different types of surgeries in the future.

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