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Phrenic nerve stimulation at the bedside in children; equipment and validation

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Phrenic nerve stimulation at the bedside in children; equipment and validation. R.I. Ross Russell, B-A. Helps, M.J. Elliot, P.J. Helms. ©ERS Journals Ltd 1993.

ABSTRACT: There is evidence that early diagnosis of postoperative phrenic nerve damage may improve outcome, by allowing early surgical treatment, in children following cardiac surgery. This has prompted the development of a simple method for measuring phrenic nerve latency at the bedside in children.

We have evaluated the reproducibility of measurements made with this system in 11 children (4 months to 13 yrs) admitted for routine surgery or cardiac catheterizations, and have assessed the various components of variability inherent in the measurement of phrenic nerve latency.

The overall variability of the phrenic nerve latency with this technique (95% confidence interval) is approximately ±1 ms, and differences greater than this between measurements are likely to reflect a real change in phrenic nerve function.

Our results indicate that the bedside technique should be a useful method of the objective assessment of phrenic nerve function in children recovering from cardiac surgery. *Eur Respir J., 1993, 6, 1332–1335.*

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The technique of transcutaneous phrenic stimulation and measurement of phrenic nerve latency was first described by SARNOFF *et al.* [1] in 1948, and normal values for phrenic nerve latency were reported by DELHEZ [2] in 1965. Clinical interest increased as the technique was adapted [3], but most of the reported studies have still required the patient to be moved to a respiratory laboratory. With increasing interest in phrenic nerve damage following cardiac surgery [4–7], especially in children [8–11], and the suggestion that early diagnosis and treatment of such damage improves outcome [12–15], a need has emerged for a bedside test of phrenic function. We therefore developed a bedside technique suitable for infants and children, and assessed its inter- and intra-patient and inter and intra-observer variabilities.

Methods

Equipment

The methods used to measure phrenic nerve latency were based on the principles described in the paper by NEWSOM-DAVIS [3]. The phrenic nerve was stimulated in the neck, just behind the posterior border of the sternomastoid muscle at the level of the thyroid cartilage, with a handheld bipolar muscle electrode, connected to a Digitimer DS1 square wave pulse stimulator (Digitimer Ltd, Welwyn Garden City, UK). An external locally built trigger, giving an output of approximately 0.5 v at a frequency of 1 Hz, was used to control the frequency of the stimulus, which was delivered as a constant current, square wave impulse, of 100 μs duration. A further signal was connected to the trigger port of the oscilloscope, so that its trace started at the beginning of each stimulus. The diaphragmatic signal (compound muscle action potential, CMAP) was recorded with self-adhesive electrocardiograph (ECG) leads (Medicotest-N-F), with a measured impedance of less than 4 Ω. The skin was cleaned with spirit, and gently abraded with a pumice stone, to ensure good electrical contact. The earth electrode was placed over the upper sternum, the active electrode over the 7th intercostal space in the anterior axillary line, and the reference electrode over the 8th rib, just lateral to the active electrode. The signal received was processed by a pre-amplifier and amplifier, (EMG 220, Biodata, Manchester, UK), and displayed on the Y-axis of a time based storage oscilloscope (Tektronix Ltd, Marlow, UK). Traces from the study were printed out on paper, using a plotter (Hewlett Packard, Bracknell, UK), or a dot matrix printer (Facit fx).

Patients

All patients studied were children, admitted for routine surgery or cardiac catheterization. Patients who had undergone previous cardiothoracic surgery were excluded, as were any patients with known neuromuscular disorders. Informed consent was obtained prior to the studies, which were performed with approval from the hospital Ethics Committee. The median age of the study population was 4.3 yrs (range 4 months to 13.2 yrs).

Observer variability

Intra-observer variability was assessed with two separate observers, each observer studying 11 patients twice within 20 min. The observers (RIRR and B-AH) had differing experience in the technique of phrenic nerve stimulation in children. RIRR had studied over 150 children prior to this study, whereas B-AH had been recently trained, and studied 20–30 children. Once the phrenic nerve had been stimulated, the CMAP trace was printed onto paper at the bedside, but latency was not measured immediately, so as to minimize bias. Once all the studies had been completed, the traces were presented in random order to the original observer and the latency measured. The variability of each observer was assessed by plotting the difference between each pair of measurements against the mean [16], and calculating the 95% confidence intervals (CI) of these differences.

Inter-observer variability was also assessed in the same 11 patients, who were independently studied by each observer within 20 min and in random order. Each observer was instructed to stimulate the phrenic nerves and to measure their latency in the same manner. Differences between values were again compared against their mean, and 95% CI derived.

In order to measure any variability in the interpretation of the paper traces, 40 separate traces were independently assessed by the same two observers. The traces were randomized and presented to one observer who measured the latency, and then randomized again and presented to the second observer, and these two sets of values compared as above.

Patient variability

Longer term variability was assessed in five stable patients in the recovery phase following cardiac surgery, and in whom the measurements of pre- and postoperative phrenic latency had shown no evidence of postoperative damage. Their ages ranged between 4 months and 12 yrs, and they were clinically stable, with normal temperatures and nutritional status throughout.

Consecutive measurements of phrenic latency were made by the same observer, at daily intervals for 7 days, and electrode positions were marked on the chest, to ensure identical positioning on subsequent occasions. To allow comparison between all patients, latencies on days 2–7 were plotted as percentages of the day 1 value.

Results

Intra-observer variability was similar for both of the two observers (fig. 1). For observer 1, the mean difference between the separate measurements was -0.036 ms, with the 95% confidence intervals for the mean±2 SD lying between -0.66 and 0.58 ms. For observer 2, the equivalent figures were -0.123 ms (95% CI -1.12 to 0.87 ms). The appearance of a slightly greater variability with observer 2 does not reach statistical significance.

Inter-observer variability showed a mean difference of 0.159 ms (95% CI of the mean±2 SD -0.70 to 1.02 ms) (fig. 2).

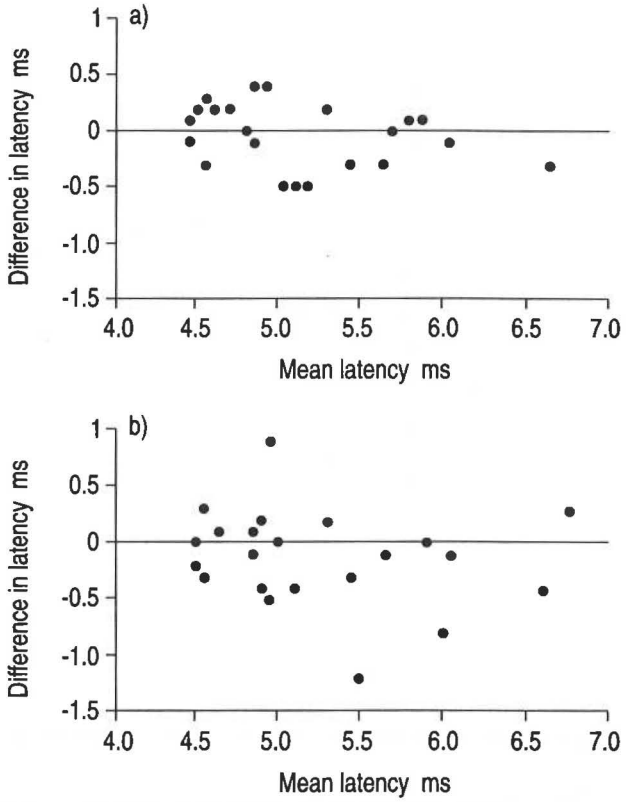

Fig. 1. – Intra-observer variability for observers 1 (a) and 2 (b).

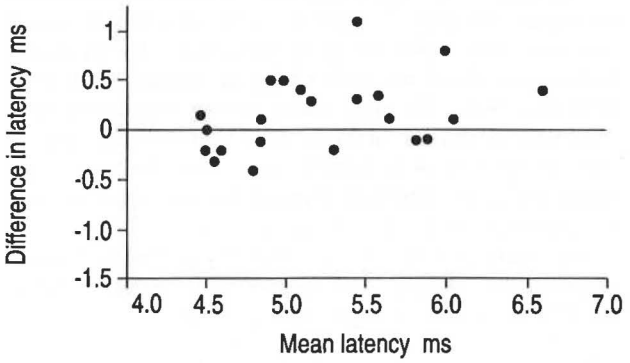

Fig. 2. – Inter-observer variability.

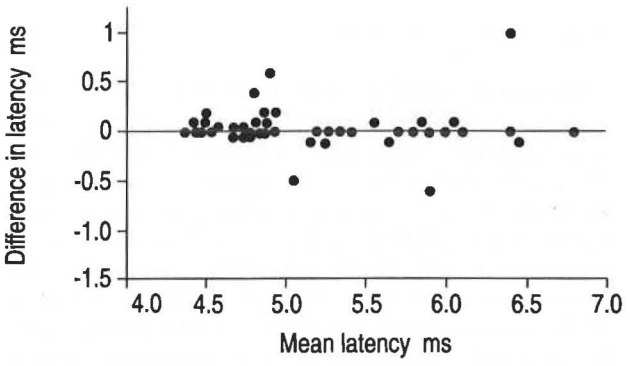

Fig. 3. – Variability in the interpretation of the trace.

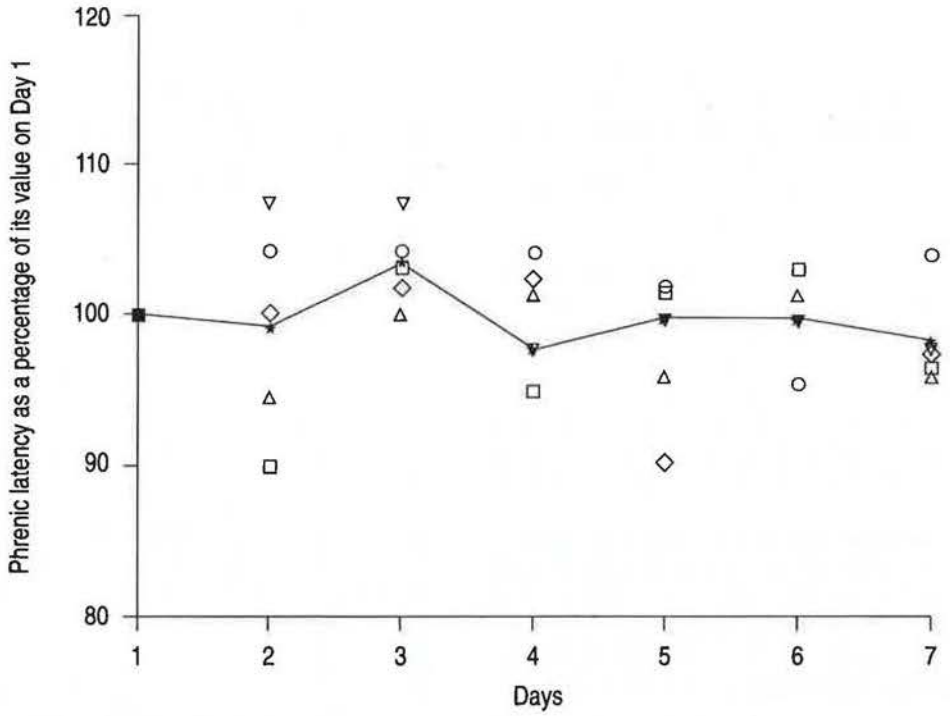

Fig. 4. – Day to day variability of phrenic latency in individual patients. The mean latency for the data is shown as a solid line.

An apparent increase in the differences with increasing latency (fig. 2) was not confirmed by linear regression ($r=0.36$, $p>0.05$).

Differences between observers for trace interpretation are shown in Figure 3, where it can be seen that all except one trace were within 0.6 ms of each other. The mean difference was -0.041 ms (95% CI for the mean±2 SD -0.59 to 0.50 ms). When the single outlier was reconsidered by both observers, an artefact in the baseline that made the start of the CMAP difficult to interpret was noted. Excluding this single trace, the difference between the measurements falls to -0.019 ms (95% CI -0.42 to 0.38 ms).

The study of longer term variability in phrenic latency showed little change, with mean values on day 7 being 99.22% (SD 4.3%) of values on day 1 (fig. 4).

Discussion

Measurement of variability

The overall variability of the technique has several components, including inter- and intra-observer variability, inter-patient variability, intra-patient (or biological) variability, and variability attributable to the equipment and method. Variability of repeated measures includes both intra-observer and biological variability, and over the short-term, it is not possible to separate the two. In order to assess the other variabilities outlined above, it had to be assumed that nerve conduction time varies very little over short periods. This is a reasonable assumption, as nerve conduction speed at any moment is dependent on the physical properties of the nerve, including myelination and size of fibres, and the ambient temperature. Over short periods of time these factors would be unlikely to change.

There was close agreement in the measured variability between and within observers, confirming that the two observers were consistent, despite their differences in experience. Some of the measurement variability was the result of trace interpretation, as shown in figure 3, and this represented approximately half of the overall variability. It can, therefore, be concluded that trace interpretation accounted for approximately ±0.4 ms, and that the technique variability accounted for a further ±0.6 ms. The combined observer/technique variability was acceptably small in relation to the range of latencies measured (4.5–6.5 ms). In order, to identify significant change in an individual reading, all these sources of variability need to be accounted for. A change of more than 1 ms would certainly be well outside these known sources of error. The technique was well tolerated by all the patients studied, and no studies were terminated due to patient discomfort. This agrees with previous work [9], showing a high percentage of successful studies in infants and children. In adult practice, poor tolerance of transcutaneous stimulation is occasionally reported [17], giving rise to the use of techniques such as electromagnetic stimulation [18], but other authors report good success with transcutaneous techniques [19, 20].

The technique for phrenic nerve stimulation described here can be used at the bedside in children recovering from cardiac surgery, and the variability of the recorded latency suggests that it is an acceptable test for assessing phrenic nerve function. In adult practice, it has been suggested that measurement of phrenic nerve latency should be routine following cardiac surgery [19], and the development of a suitable technique for paediatric practice would allow a critical assessment of the same question in children.

There is some discussion about the most appropriate positioning for the chest electrodes for recording diaphragmatic CMAP. The positioning used in the present study is closest to that used by RAIMBAULT *et al.* [21] in children, and MACLEAN and MATTIONI [22] and SHAW *et al.* [23] in adults, and was chosen because in adults it appears to be the site where the right and left latencies are most likely to be the same [24]. This has obvious advantages, in that it should allow the contralateral latency to be used as a control value, and should also enable the operator to study the side unencumbered by wound dressings.

Summary

Despite the many studies of phrenic stimulation in the adult population, the relative paucity of data in infants and children, and the need to make the equipment portable, have necessitated a thorough review of the reliability and reproducibility of the technique in the study population.

The reported technique has similar inter- and intra-observer variability, with 95% confidence intervals of 1 ms. This figure includes variability in the trace interpretation (0.4 ms) and measurement (0.6 ms). Inter-observer differences appeared to be increased at higher latencies, but this did not reach statistical significance. The longer term (1 week) variability of phrenic latency is small, and clinically unimportant compared to the measurement variability.

We have identified the various components of variability in the measurement of phrenic nerve latency at the bedside, and conclude that it represents a useful tool in the investigation of children, who may be at particular risk of postoperative phrenic damage.

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