Measurement of twitch transdiaphragmatic pressure: surface versus needle electrode stimulation

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Abstract

The transdiaphragmatic pressure (Pdi) generated during bilateral supramaximal phrenic nerve stimulation at 1 Hz from surface stimulating electrodes was compared with pressures obtained from needle electrodes inserted under local anaesthesia. Surface electrodes were used to obtain diaphragmatic electromyograms and magnetometers to monitor rib cage and abdominal configuration. Twitch Pdi was recorded at functional residual capacity in three normal subjects. Mean (SD) twitch Pdi in the three subjects during stimulation with surface electrodes was 19·4 (1·8), 22·5 (1·1), and 29·3 (2·2) cm H_2O compared with 12·9 (1·5), 17·4 (1·3), and 22·6 (3·0) cm H_2O with needle stimulating electrodes. Thus phrenic nerve stimulation with needle electrodes was more complicated and more invasive than stimulation with surface electrodes and resulted in lower transdiaphragmatic pressures.

Transdiaphragmatic pressure generated during bilateral supramaximal phrenic nerve stimulation at 1 Hz (twitch Pdi) has been used to assess diaphragmatic contractility. Some workers have used percutaneous stimulation[1,2] whereas others have suggested that needle stimulating electrodes are more reliable and comfortable than surface electrodes.[3] The present study was performed to determine whether the twitch Pdi generated by needle electrodes was higher than that produced by surface electrodes to help determine which method is better in the assessment of twitch Pdi.

Methods

Diaphragm muscle action potentials were recorded with surface electrodes in three normal subjects (two male, one female, aged 30–43 years), who gave verbal informed consent. Pdi measured with balloon catheters[4] at functional residual capacity (FRC) was used as a zero reference point. Two pairs of linearised magnetometer coils (NH Peterson, Boston, Mass) were used to monitor changes in rib cage and abdominal anteroposterior dimensions.[5] The phrenic nerves were stimulated bilaterally in the supraclavicular region with single shocks at 1 Hz. Square wave impulses 0·1 ms in duration were obtained from a dual output isolated stimulator. Recordings were made with the subject relaxed and wearing a noseclip at FRC, in the supine posture with one pillow. The voltage of stimulation was raised until there was no further increase in the size of either diaphragm muscle action potentials or twitch Pdi; voltage was increased by a further 10% to ensure supramaximal stimulation and varied from 80 to 160 volts for each nerve. Measurements were made on five days over 17 months with bipolar stimulating electrodes (Medelec 53054) with felt tips 5 mm in diameter. Fifty to 80 twitches were recorded in each subject on each day.

Phrenic nerve stimulation was then performed with needle stimulating electrodes (DISA 13L65) 40 mm in length and 0·4 mm in diameter. These were inserted with the subject leaning back in a chair, by an experienced investigator using local anaesthesia with lignocaine. The needles were advanced slowly until phrenic nerve stimulation occurred. The voltage of stimulation was then increased until there was no further increase in twitch Pdi and evoked diaphragm muscle action potentials. The voltage used was increased by a further 10% and varied from 3 to 4 volts for each nerve. A gap of about 2 cm lay between the two needle electrodes so that the cathode was always closer to the clavicle than the indifferent electrode. Fifty five to 80 twitches were recorded in each subject on each day. Care was taken to measure only twitches that were shown on the magnetometer and Pdi traces to have been performed at FRC; other twitches were rejected.

Group data were expressed as means and standard deviations. Comparisons of needle and surface data were tested for statistical significance by the two tailed paired Student's *t* test.

Results

Stimulation of both phrenic nerves was successful in all three subjects. Although no undue discomfort was experienced during stimulation using surface electrodes, all the subjects experienced local pain during insertion of the local anaesthetic and deep pain in the area of the scalene muscles during stimulation with the needle electrodes. Two subjects had local tenderness and bruising at the stimulation site for two days after the procedure.

Mean (SD) twitch Pdi obtained with surface electrodes at FRC on the five separate days was 19·4 (1·8), 22·5 (1·1) and 29·3 (2·2) cm H_2O. Twitch Pdi obtained with needle electrodes at FRC was lower (figure): 12·9 (1·5), 17·4 (1·3), and 22·6 (3·0) cm H_2O respectively ($p < 0·01$).

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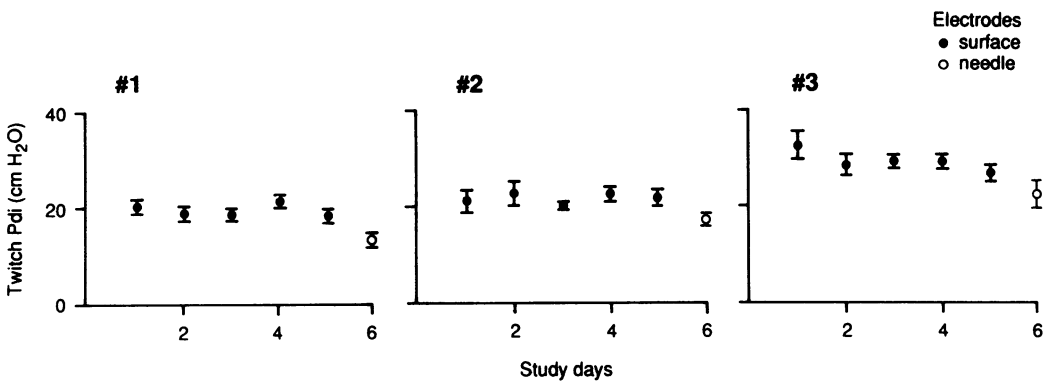

Figure Transdiaphragmatic pressure recorded during bilateral supramaximal phrenic nerve stimulation at 1 Hz (twitch Pdi) in three subjects with surface stimulating electrodes on five separate days and with needle electrodes on one day (mean values with standard deviations).

Discussion

Twitch Pdi obtained during stimulation with surface electrodes was higher than that obtained with needle electrodes. We performed studies on five separate days with surface electrodes. As previously reported,[6] there was some day to day variability in the results, but this was less than the decrease in twitch Pdi seen when needle electrodes were used. We studied the latter technique on one occasion only as it was invasive and unpleasant for the subjects. The needles were inserted by an experienced investigator who had performed the technique on many previous occasions and who was confident that his positioning of the needles was optimal. We ensured that the stimulating voltage was supramaximal as judged by the height of twitch Pdi and the size of diaphragm muscle action potentials. Despite this, twitch Pdi obtained during stimulation with needle electrodes was lower in all three subjects.

Twitch Pdi has been shown to vary significantly with lung volume and rib cage configuration.[7,8] We ensured that stimulation had occurred at FRC by looking carefully at magnetometer traces of rib cage and abdominal movement and at traces of Pdi; only twitches obtained during relaxation at FRC were analysed for both surface and needle stimulating electrodes. Differences in lung volume or rib cage configuration are therefore unlikely to have been responsible for the differences in twitch Pdi with the two techniques.

An alternative explanation may have been the difference in posture for the two techniques. Subjects were supine with one pillow for stimulation using surface electrodes, and more upright during needle stimulation. Possibly therefore the diaphragm was shorter during needle stimulations and as a result of the relation between length and tension less transdiaphragmatic pressure might have been generated. Previous work, however, investigating the effect of posture on twitch Pdi showed no significant difference between twitches performed in the seated and supine postures.[9] We conclude that difference in posture could not have accounted for the substantial difference in twitch Pdi between surface and needle stimulating electrodes.

To avoid anodal block when using needle electrodes, we took care to place the cathode nearer to the clavicle so that the direction of the stimulating current could not have caused blockade of the nerve distally. Thus anodal block does not explain our finding.

Stimulation using needle electrodes occurs around the needle point so despite our efforts the needle electrodes might not have recruited all motor units. Other workers have recently reported lower twitch Pdi with needle stimulating electrodes than with surface electrodes and concluded that the needle electrodes could not be positioned easily in the neck, so that optimal stimulation was difficult.[10] Thus the lower twitch Pdi may have occurred because part of the phrenic nerve was not stimulated by the needle electrode. If this was the cause of the problem it may be unavoidable and investigators need to be aware of it.

Thus stimulation using needle electrodes not only was more complicated and invasive but resulted in a lower twitch Pdi than surface electrodes. We are unable to provide a definitive explanation for our results. As phrenic nerve stimulation using surface stimulating electrodes appears to be a simple and easily learnt technique,[11] surface stimulation may be used reliably in the clinical investigation of patients with respiratory muscle dysfunction.

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