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Lateralization of Sympathetic Control of the Human Sinus Node:

ECG Changes of Stellate Ganglion Block

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In the past decade there has been a growth of interest in the relationship between alterations in sympathetic tone to the heart and the production of cardiac arrhythmias.[1–3] In fact, unilateral alteration in right- or left-sided sympathetic tone to the heart is the mechanism postulated for the production of electrocardiographic (ECG) changes in an increasing variety of clinical conditions ranging from cerebrovascular accidents[4,5] to the prolonged-QT-interval syndromes.[6] There is little evidence in man, however, that there is any underlying difference between right- and left-sided cardiac sympathetic innervation that could be responsible for these ECG changes. The use of stellate ganglion block offers an opportunity to evaluate the possible ECG effects of unilateral alteration in sympathetic tone to the heart in man. In particular, by observing the differential effects on heart rate of right and left stellate ganglion blocks, we evaluated whether lateralization of sympathetic innervation of the sinus node existed in man. This paper reports the results of our studies of this phenomenon.

METHODS

All patients included in the study were undergoing either right or left stellate ganglion block for evaluation of pain relief by sympathectomy of traumatic causalgia of the upper extremity. The patients ranged in age from 27 to 54 years, were free of cardiac disease, and had normal electrocardiograms. Permission to perform this study was obtained from the Human Studies Committee.

Each patient was brought to the operating room without premedication and, on arrival, a lead II rhythm strip was obtained. The patient then underwent a stellate ganglion block by the method described by Moore,[7] using a percutaneous injection of 10–15 ml of lidocaine, 1 per cent, without epinephrine. No other medication was used. After the injection but prior to onset of the block, a repeat lead II rhythm strip was obtained in order to selectively assess the effect on heart rate of the procedure itself. Documentation of a successful stellate ganglion block was determined by the development of a Horner's syndrome, as well as by an increase in skin temperature and change in galvanic cutaneous response in the affected upper extremity. Forty-five minutes after the block had been placed, a repeat lead II rhythm strip was obtained. All heart rate changes were analyzed by Student's t test, with differences considered significant when $P < 0.05$.

In an additional group of 11 patients, a more prolonged evaluation of the effects of stellate ganglion block was desired. As a result, in these patients the block technique was modified to permit placement of a percutaneous indwelling catheter so that multiple stellate ganglion blocks could be given without subjecting the patients to repetitive injections. Investigation of the effects of stellate ganglion block on heart rate in these patients was conducted in the manner described above.

RESULTS

Right stellate ganglion block performed 24 times in 17 patients decreased heart rate from a mean resting control value of 86 ± 5 (SD) to 72 ± 4 beats/

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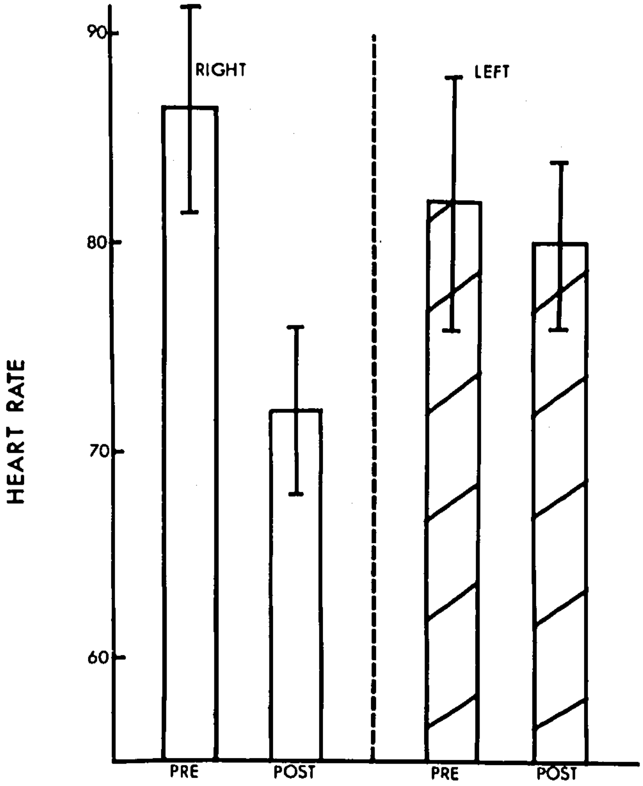

FIG. 1. Comparison of the effects on heart rate of percutaneous right and left stellate ganglion blocks. See text.

min (fig. 1). This difference was statistically significant ($P < 0.01$). It is noteworthy, however, that the stress to the patient involved in the performance of the procedure transiently increased heart rate prior to the onset of the block to 106 ± 8 beats/min.

In contrast, left stellate ganglion block, performed 14 times in 11 patients, failed to produce significant slowing of heart rate (fig. 1). Pre-block control heart rate was 82 ± 6, while post-block rate was 80 ± 4 beats/min. However, once again the performance of the procedure transiently increased heart rate prior to the onset of the block, to 104 ± 8 beats/min.

With the use of an indwelling catheter, right stellate ganglion block was performed 16 times in six patients. Pre-block control heart rate was 80 ± 6 beats/min, and there was a significant slowing to 69 ± 5 beats/min following onset of the block ($P < 0.05$).

Left stellate ganglion block was performed 12 times in five patients. Pre-block heart rate was 82 ± 5 beats/min, and the post-block value, 77 ± 4 beats/min, did not represent a significant slowing. The use of the indwelling catheter technique did not cause significant transient tachycardia at the time of the procedure with either right- or left-sided block.

Discussion

It has been shown in anatomic studies in dogs that the sympathetic accelerator fibers are more prominent on the right than on the left,[8] that stimulation of the right stellate ganglion results in tachycardia that does not occur following left stellate ganglion stimulation,[9] and that the mechanism for this is probably a difference in distributions of fibers from the right and left stellate ganglia.[9] Thus, it is well established that in the dog there is right-sided sympathetic predominance of sympathetic innervation of the sinus node. Despite these animal experiments, however, it does not necessarily follow that this is also true in man. Autonomic innervation of the heart appears to vary greatly among species, as previous studies in the dog by Yanowitz *et al.*[10] and in the cat by Rogers *et al.*[11] have demonstrated. As a result, we believed that only human data would show whether the distribution of sympathetic fibers would have a right stellate predominance with regard to sinus node function in man.

Stellate ganglion block does permit evaluation of the effects on heart rate of unilateral alterations in sympathetic tone in man. The widespread use of this technique, the previous animal experiments on this phenomenon, and the sporadic reports of bradycardia induced by stellate ganglion block[7] raise the question why the differential heart rate-slowing effects of right- and left-sided block had not been previously appreciated. We believe that the answer is contained in our data. As we found in the course of our initial experiments, the nature of the procedure itself involves some pain as the block is commonly done, and this defeats the purpose of evaluating any change in heart rate. While we did find a significant slowing of heart rate following standard right stellate ganglion block, we did not believe this was necessarily valid, because of the tachycardia produced by the block procedure itself.

The opportunity to study the effects on heart rate of stellate ganglion block by the use of the indwelling catheter technique produced a more convincing demonstration of the functional lateralization of sympathetic innervation of the sinus node in man. The catheter technique demonstrated without any intervening prominent tachycardia that only the right stellate ganglion block resulted in significant bradycardia. This demonstrates that there are different patterns of rightand left-sided sympathetic cardiac innervation in man, and that the right stellate ganglion has a much greater influence on heart rate than does the left stellate ganglion. Furthermore, it appears that the heart may receive its autonomic innervation in an intricate pattern that may have some yet undefined functional importance.

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Accidental Ventilator-induced Hyperventilation

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We report below a case in which the patient was accidentally hyperventilated as a result of erosion of a ventilator bellows.

REPORT OF A CASE

A 53-year-old man weighing 65 kg was brought to the operating room for aortofemoral bypass under general anesthesia. Past history revealed myocardial infarction several years previously, but the patient was not taking any medication at the time of admission.

Preoperative medication included morphine, 10 mg, hydroxyzine, 100 mg, and glycopyrrolate, 0.2 mg, im, 45 minutes prior to induction of anesthesia. In addition to two intravenous lines, a left radial arterial catheter was inserted, as well as a subclavian line for central venous pressure (CVP) monitoring.

The patient received thiamylal, 400 mg, for induction. Tracheal intubation was facilitated by the use of succinylcholine, 100 mg. Anesthesia was maintained with 66 per cent nitrous oxide and supplementary morphine. Neuromuscular block was achieved with *d*-tubocurarine, monitored with a peripheral nerve stimulator.

Approximately 30 minutes into the procedure, an Ohio® anesthesia ventilator was connected to the anesthesia machine. The tidal volume of 650 ml was set at a rate of 10/min. Shortly thereafter, the patient's blood pressure fell from 140/70 to 80/30 torr, while CVP rose from 10 to 20 cm H_2O. Arterial blood-gas determinations showed *p*H 7.60, P_{CO_2} 17 torr, and P_{O_2} 200 torr. A Wright respirometer was then inserted in the expiratory part of the system, and a tidal volume of 1,700 ml was measured. Removal of the ventilator from the system resulted in rapid return of vital signs to previous levels. Repeat blood-gas determinations revealed *p*H 7.55, P_{CO_2} 22 torr, and P_{O_2} 115 torr. The operation then proceeded without incident. Examination of the ventilator revealed numerous small erosions penetrating the wall of the bellows.

DISCUSSION

The ventilator is similar in method of operation to many other commercially-available ventilators. A concertina-type bellows fills with the gas to be inhaled, which is forced into the lungs by compressed gas (oxygen) on the outside of the bellows. This is accomplished utilizing the fluidic principle. Other ventilators utilizing a series of lightly-loaded spring valves are also commercially available.[1]

In this case, the concertina had holes in it. The compressed gas driving the machine was 100 per cent oxygen at 50 psi; during inhalation, large quantities of oxygen at this high pressure were added to the intended inhaled gas mixture. This resulted in a tidal volume of 1,700 ml, as opposed to the preset tidal volume of 650 ml. A reduction in blood pressure with concomitant increase in CVP and a high airway pressure alerted the anesthesia personnel to the problem, and it was quickly rectified. Fortunately, there was no serious ill effect. However, if the driving gas had been air, the $F_{I_{O_2}}$ could be lower than expected.

The four Ohio® ventilators in our department were examined, and a similar partial erosion of a ventilator bellows was found in a second machine.

It is the intent of this report to alert others to the possibility of this complication and to encourage routine examination of the ventilator, particularly the rubber portions, before use. It is recommended that a respirometer routinely be used to check tidal volume, as opposed to relying upon the ventilator setting.

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