Spinal cord stimulation significantly decreases the need for acute hospital admission for chest pain in patients with refractory angina pectoris

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Abstract

Objective—To assess the impact of spinal cord stimulation (SCS) on the need for acute admissions for chest pain in patients with refractory angina pectoris.

Design—Retrospective analysis of case records.

Patients—19 consecutive patients implanted for SCS between 1987 and 1997. All had three vessel coronary disease, and all were in New York Heart Association functional group III/IV.

Methods—Admission rates were calculated for three separate periods: (1) from initial presentation up until last revascularisation; (2) from last revascularisation until SCS implantation; (3) from SCS implantation until the study date. Post-revascularisation rates were then compared with post-SCS rates, without including admissions before revascularisation, as this would bias against revascularisation procedures.

Results—Annual admission rate after revascularisation was 0.97/patient/year, compared with 0.27 after SCS (p = 0.02). Mean time in hospital/patient/year after revascularisation was 8.3 days *v* 2.5 days after SCS (p = 0.04). No unexplained new ECG changes were observed during follow up and patients presented with unstable angina and acute myocardial infarction in the usual way.

Conclusions—SCS is effective in preventing hospital admissions in patients with refractory angina, without masking serious ischaemic symptoms or leading to silent infarction.

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Keywords: spinal cord stimulation; refractory angina pectoris; admission rate; cost effectiveness

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Spinal cord stimulation (SCS) is an effective treatment for chronic angina pectoris refractory to both medical and surgical management.[1–6] Many investigators have described a primary anti-ischaemic effect, assessed by exercise tests,[2–5] ambulatory ECG recordings,[5 6] stress echocardiography,[7] and right atrial pacing studies with coronary sinus lactate assays.[8] It is claimed that it is this anti-ischaemic action which accounts for the improvement in symptoms. Anderson *et al* published data in 1995 showing a reduction in both the number and duration of admissions after SCS implantation[9]; however, patients were separated into those who responded well to the treatment and those in whom there was minimal response. The groups were then analysed separately and admission rates were not directly compared. In this study we specifically examined the number of admissions and the length of stay of patients before and after SCS implantation. Acceptance of SCS has been limited by concern that the procedure may be harmful, though there is evidence that SCS does not mask acute myocardial infarction.[10] An additional aim of our study was therefore to examine this claim, as well as documenting the causes of acute admission after SCS implantation.

Methods

We examined the case records of 19 consecutive patients implanted with SCS units at Taunton and Somerset Hospital between 1987 and 1997. All the patients had triple vessel coronary disease diagnosed at angiography, and experienced angina in New York Heart Association (NYHA) functional class III or IV. All the patients were considered unsuitable for further revascularisation. Fifteen of them had undergone previous revascularisation procedures (13 coronary artery bypass grafting (CABG), two percutaneous transluminal coronary angioplasty (PTCA)), and four were deemed unsuitable for any type of procedure. In the last, the starting point for assessing admissions before SCS was when the decision was made that they were unsuitable for a revascularisation procedure; from that time on, they were analysed in the "post-revascularisation" group.

All admissions for each patient were analysed, but only those caused by chest pain or suspected ischaemic heart disease were considered in the analysis. The admission notes, ECG records, and blood tests were reviewed to ensure that a correct diagnosis was reached in each case. If it was suspected that the origin of the pain was not cardiac, but no other clear aetiology was present, the admission was still counted and analysed—thus in case of doubt the pain was considered to be ischaemic. Admissions for other proven causes of chest pain (for example pleuritic pain or oesophagitis) were not included in the study. Admissions for cardiac investigations (coronary angiography) and revascularisation procedures (CABG and PTCA) were not included, nor were the admissions for SCS implantation itself.

The length (in days) of each admission was calculated. To ensure accuracy, this was

Table 1 Patient characteristics and drug treatment before implantation

Total	19
Men	14
Women	5
Previous MI	12
Non-Q wave MI	10
Diabetes mellitus	6
Previous CABG	13
Previous PTCA	2
Triple vessel disease, with symptoms in NYHA class III/IV	19
Drug treatment	
Oral nitrates	19
Calcium channel blockers	19
β Blockers	11
Potassium channel openers	13
All four of the above	8

CABG, coronary artery bypass graft; MI, myocardial infarction; NYHA, New York Heart Association functional class; PTCA, percutaneous transluminal coronary angioplasty.

checked against the patient database on the hospital's computer system, and any discrepancies were investigated. We were therefore confident in ensuring that all admissions had been accounted for, and that the length of stay and diagnoses were accurate. Patients were followed up at least six monthly after implantation, with ECG records at each visit. New changes on ECG were looked for and assessed.

CALCULATION OF YEARLY ADMISSION RATES

Owing to the progressive nature of coronary disease, the data were considerably skewed, with the number of admissions increasing in frequency over time. The time period between each intervention was variable and was therefore an unreliable baseline for comparison. In order to overcome this, hospital admission rates were considered per year in three periods:

- The first period was the time from first presentation up until the most recent CABG or PTCA.
- The second phase extended from the final CABG or PTCA up until SCS implantation (named the post-revascularisation period).
- The third period was from SCS implantation up to the study date (31 December 1997).

The admission rate after revascularisation was then compared with the admission rate after SCS.

STATISTICAL ANALYSIS

As the data were not normally distributed and were related to two measurements in one individual, the Wilcoxon matched pair test was performed, with a p value of < 0.05 being regarded as statistically significant.

Results

The baseline characteristics of the patient group are shown in table 1. All patients were taking maximum tolerated doses of standard antianginal drugs in combination; after implantation this treatment was continued unaltered. The mean follow up period was 2.78 years (0.8 to 9.0). There have been two deaths within the group; the first was caused by coincidental lung carcinoma and the second by progressive heart failure in a patient with severe aortic stenosis who refused surgery.

Table 2 Admission rates before and after interventions

	Before revascularisation	After revascularisation	After SCS
Time period (years)	1.23	4.5	2.74
Mean rate of admission/ patient/year	1.02	0.97*	0.27*
Mean No of days/ year in hospital per patient	6.24	8.3†	2.55†

SCS, spinal cord stimulation.
*p=0.02; †p=0.04

Table 3 Breakdown of admissions after implantation for spinal cord stimulation

Cause of admission	No of admissions
Unstable angina	6
Acute myocardial infarction	3 (includes 2 non-Q wave)
Battery "end of life"	2
?Non-cardiac chest pain	4

The hospital admission rates for each period are shown in table 2. Implantation of SCS led to a fall in admissions, with a decrease in the rate of admissions per patient from 0.97/year to 0.27/year (p = 0.02).

The duration of admissions following SCS implantation (table 2) also fell, the mean duration per patient of 8.3 days/year falling to 2.6 days/year (p = 0.04).

Twelve patients did not require admission at all after SCS, the remainder accounting for all the post-SCS admissions. The admissions in the post-SCS implant period broken down by cause are shown in table 3. Most admissions were for unstable angina and acute myocardial infarction. Two patients had admissions that were thought to be non-cardiac by the time of discharge. In two other cases the devices were found to have expired batteries ("end of life"). There were three myocardial infarctions—one transmural infarct (accompanied with a ventricular fibrillation arrest) and two non-Q-wave infarcts. In all cases these patients presented with typical symptoms and were treated in the conventional manner. Follow up of patients has not revealed unexplained ECG changes, and we therefore conclude that all serious cardiac events did present to hospital.

Discussion

Several studies have shown that SCS has beneficial effects upon ischaemia.[2–8] However, it was formerly unknown whether these benefits might have a significant impact on the need for hospital admission. While there is good evidence that patients feel physically and psychologically better following SCS implantation,[11] it is reassuring to know that the use of these relatively expensive devices decreases hospital admissions. We did not do a formal cost–benefit analysis, but table 4 gives an estimate of the costs involved. The figures are based upon the assumption that each admission consisted of 24 hours on a coronary care unit, with the remainder of the admission spent upon the general cardiology ward. From this the estimated costs per patient–year have been calculated. While these figures are not intended to give an accurate analysis, the magnitude of the difference is impressive.

Table 4 Estimate of costs per patient–year

	Before SCS	After SCS
24 hours on CCU	£850	£850
Rest of admission on ward	£1460 (£200 × 7.3 days)	£320 (£200 × 1.6 days)
Total	£2310	£1170
Annual admission rate	0.97	0.27
Total per patient–year	**£2240.70**	**£315.90**

CCU, coronary care unit; SCS, spinal cord stimulation.

SAFETY ISSUES WITH SCS

SCS offers an effective treatment which is safe; the mortality associated with implantation is zero and the morbidity is less than 1.5%,[12] an important point when considering the other options open to those with refractory angina (such as transmyocardial laser revascularisation or cardiac transplant). Indeed Mulcahy *et al* (writing in 1994) felt that SCS was underused.[13] The main obstacle to its wider acceptance appears to be the concern that SCS might mask angina, thereby depriving a patient of a warning signal. This concern is expressed both by doctors and by the patients themselves; it has grown from the belief that SCS works by the "gate theory" of pain. While it is true that devices such as SCS and TENS were developed in response to this theory, it was the serendipitous discovery that vascular ulcers were seen to heal when SCS was used in patients with painful peripheral vascular disease that led to the notion that SCS has specific anti-ischaemic effects.[14–20] In the case of angina pectoris the ischaemic threshold is indeed increased—that is, ischaemia still occurs, but it does so at a higher level of myocardial work than previously. This has been elegantly demonstrated by Mannheimer *et al* using right atrial pacing as a stressor, and calculating lactate extraction and production as an objective measure of ischaemia.[8] They showed that SCS increased the time taken for lactate extraction to become production, with the typical symptoms of ischaemia occurring at this new level. In other words, the patient still developed (and recognised) angina, but at a higher level of myocardial work. Furthermore Anderson *et al* showed that there was no excess of mortality in a group of 50 SCS patients when compared with data from the CASS register.[10] They found that patients with acute infarcts were aware of the pain despite the SCS unit. This is reflected in our data, which show that those individuals unfortunate enough to suffer further severe ischaemia and infarction while being treated with SCS still present to hospital. We have not observed an excess mortality, and the two deaths within the group were not caused by acute coronary syndromes.

SCS is a relatively simple treatment to use, and the implantation technique is not much more invasive than permanent cardiac pacing. The most difficult part of the procedure is the insertion of the electrode, as it has to be sited in the epidural space and carefully positioned to produce stimulation in the area where angina is perceived. This technique is relatively easy in the hands of an experienced individual, such as an anaesthetist, as the basic technique is the same for insertion of epidural lines. The implantation is carried out under local anaes-thetic with sedation. Occasionally a light general anaesthetic may be used during the second stage of implantation as the "tunnelling" of the electrode from the spine to the device (usually in the axilla or subpectoral region) can be traumatic to some patients.

MECHANISM OF ACTION

There has been much speculation about the mode of action, but recent positron emission tomography (PET) studies have suggested that SCS produces a redistribution of myocardial flow from non-ischaemic to ischaemic areas.[21] This has been compared with the effects of theophyllines in angina, which are also thought to act through this so called "Robin Hood" effect.[22 23] The basis for this is thought to be adenosine antagonism, reducing adenosine mediated steal phenomena. Further evidence suggesting an adenosine blocking mechanism is the fact that SCS appeared to attenuate the effects of dipyridamole (which blocks endogenous adenosine breakdown) in the study protocol used by Hautvaust *et al*.[21] Previously the hypothesis that SCS exerted an antisympathetic response was popular.[12 24] Mannheimer's group recently showed that SCS reduced peripheral sympathetic drive induced by right atrial pacing; the same study also examined noradrenaline spillover from the myocardium itself, but failed to show a difference.[25] The technique, however, is crude and may not have been sensitive enough to detect any effect from SCS.

If SCS does act through an adenosine blocking effect, then we might also speculate that this particular group of patients possess particular characteristics that allow them to respond to this treatment. The majority of these patients not only had severe coronary disease but also extensive collateral vessels; it has been shown that these vessels are more susceptible to adenosine mediated steal syndromes than native vessels.[26] It is also of interest to note that 53% of these patients have had non-Q wave myocardial infarcts previously (perhaps a disproportionate number, as non-Q wave myocardial infarction usually accounts for only 20–30% of all myocardial infarcts[27])—possibly reflecting a tendency to have more subendocardial ischaemia. Subendocardial ischaemia is thought to be exacerbated by adenosine mediated transmyocardial steal.[26] Thus this group of patients could be self selected responders to SCS.

Indeed this group of patients seems to be unique—despite having severe coronary disease they are actually survivors, which ironically is one of the major problems. They have often survived multiple infarcts, but they still continue to have regular admissions and the attrition rate is low, as we have already seen. Hospital admissions are prolonged, as further treatment options are limited. The cost of SCS is relatively high (approximately £6000), but a bed on the coronary care unit in our hospital costs approximately £850 a day, and the general cardiology ward costs around £200 a day (table 4). The device undoubtedly improves the patient's symptoms, and it is likely

that the reduction in the need for hospital admissions will cover the initial outlay for the device (within three years according to our estimates in table 4).

In summary, SCS is a safe, well tolerated, and effective treatment for refractory angina. It is relatively simple to employ, and has a perioperative mortality of zero, and little morbidity. The effects of this treatment are powerful enough to decrease the need for hospital admission without apparently masking acute coronary syndromes or producing excess mortality, even several years after implantation.

LIMITATIONS OF THE STUDY

This was a retrospective observational study and there is no placebo control group included. Patients have acted as their own controls by comparing admission rates before and after SCS in a non-randomised fashion. Thus we cannot rule out the possibility of placebo effect, although we feel the persistence of benefit with SCS (up to nine years in some patients) makes it unlikely that placebo response is the sole mechanism of action.

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