Use of laser Doppler flowmetry and transcutaneous oxygen tension electrodes to assess local autonomic dysfunction in patients with frozen shoulder

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Summary
The laser Doppler flowmeter (LDF), which measures changes in cutaneous blood flow, and the transcutaneous oxygen electrode which measures cutaneous perfusion, were used to study reflex changes in the microcirculation of the shoulder in 38 patients with frozen shoulder and 10 normal controls. In all controls and 22 patients with frozen shoulder, a normal LDF response to inspiration/expiration was observed. In 16 patients with frozen shoulder, LDF responses were either unilaterally or bilaterally absent. Comparison between the two patient groups showed a significant association ($\chi^2=6.43$, $P<0.02$) between abnormality of response and the persistence of pain. TcPo_2 was in the normal range in all patients and controls. These findings suggest that the LDF together with the TcPo_2 may be a useful method of studying the skin microcirculation over the shoulder.

Introduction
Frozen shoulder is a common clinical condition of unknown aetiology although clinical, radiological and thermographic studies have suggested an association between the disorder and chronic cervical spine disease[1]. An explanation which has been proposed for this association is that frozen shoulder results from a local abnormality of autonomic dysfunction.

Most currently available methods for assessing autonomic dysfunction, such as measurement of the variation of the RR interval or heart rate response to standing, indicate generalized rather than localized abnormalities[2]. Laser Doppler flowmetry (LDF), a technique which measures changes in cutaneous blood flow, and transcutaneous oxygen tension measurement (TcPo_2) which measures cutaneous oxygen tension, have recently been used to study reflex changes in the skin microcirculation in hands and feet of patients with spinal cord transections[3]. These cutaneous vasomotor reflexes were originally described by Bolton *et al.*[4] who used plethysmography to record changes in the hands. The existence of cutaneous vasomotor reflexes has been demonstrated in the digits of both hands and feet where extensive arteriovenous shunts exist. It has not yet been established that such reflexes can be detected reliably in areas other than the phalanges. These methods were used in a study of patients with frozen shoulder and healthy control subjects.

Patients and methods
Thirty-eight patients presenting consecutively to the Rheumatology Department at Southampton General Hospital with frozen shoulder were studied. Diagnostic criteria for the condition were: (a) shoulder pain of more than three weeks' duration, (b) limitation of active and passive movement in all directions with reduction in external rotation of 50%, and (c) no other cause of shoulder arthritis by clinical, haematological or radiological examination[5]. These patients were compared with 10 healthy volunteer controls. Patients with diabetes mellitus, ischaemic heart disease, stroke or Raynaud's phenomenon were excluded from the study.

LDF and TcPo_2 studies were carried out with the patients seated in a room which was free from draughts, noise and vibration and where the ambient temperature was maintained at 21-24°C. They were initially rested for at least 15 min in the room before tests commenced. Smokers were requested to abstain for 2 h prior to testing.

Subjects were seated with their hands resting at the level of their hearts throughout the tests. An LDF probe (Perflux PFIC, Perimed Sweden) was positioned on degreased and dry skin in the C-5 dermatome on the outer aspect of the shoulder overlying the deltoid muscle and held in position with double sided adhesive discs. The output signal from the LDF was fed into a two channel recorder (Devices MK2, UK). Blood flow was recorded at rest for 10 min and following single, short deep inspiration/expirations and coughs. This procedure was repeated on each shoulder and thumb. A Roche Dual oximeter (632) was used to measure TcPo_2 at 43°C on both shoulders within 2 cm of the site where the LDF probe was positioned.

Results
The mean age of the patients with frozen shoulder was 63 years (range 34-82 years) and the mean duration of symptoms was 11 months (range 1-32 months). Sixteen of the patients (24%) had persisting pain in the shoulder at the time of measurement and 34 (89%) had persisting restriction of passive shoulder movement. The mean age of the 10 healthy controls was 30.9 years (range 24-37 years).

Figure 1 shows a typical waveform obtained from a healthy control subject and demonstrates the vasoconstrictor response to inspiration/expiration.

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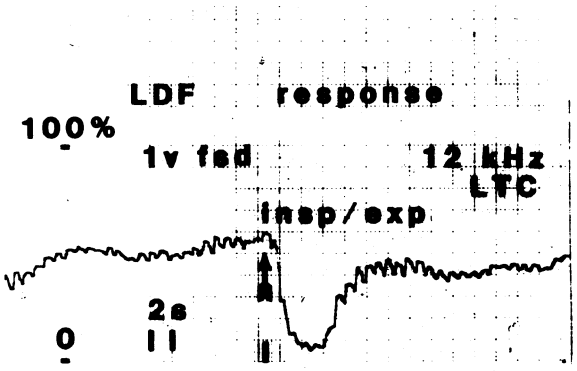

Figure 1. Typical waveform from a healthy subject

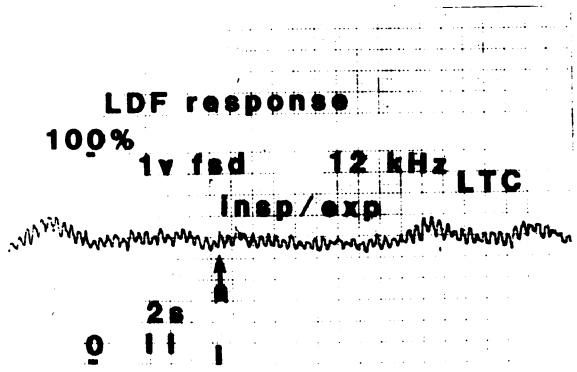

Figure 2. Waveform from a patient with frozen shoulder

Table 1. Laser Doppler flowmetry responses in patients with frozen shoulders and controls

	Frozen shoulder	*Controls*
Number	38	10
Bilateral normal	22	10
Unilateral absent	9	—
Bilateral absent	7	—

Table 2. Clinical features in patients with frozen shoulder according to laser Doppler flowmetry response

	Normal	*Impaired*
Number	22	16
Duration of symptoms (months)	9.5	10.4
Number with persisting pain●	5	11
Shoulder abduction (degrees)	84.5	76.3
Cervical spine lateral flexion (degrees)	36.4	30.9

The values expressed for symptoms, shoulder abduction and cervical lateral flexion are the respective means
●$\chi^2=6.43$, $P<0.02$

The characteristic feature of the normal vasoconstrictor response is a transient reduction in baseline flow with a concomittant dimunition of cutaneous pulsatility.

Figure 2 shows the waveform obtained from one of the patients with frozen shoulder. There is no change in baseline flow or reduction in pulsatility in response to inspiration/expiration. The LDF traces were examined by one of us (RM) and an unbiased observer. The concordance between observers was 76.9%.

All 10 healthy controls showed normal vasoconstrictor responses to inspiration/expiration. Table 1 shows that in 22 of the 38 patients (58%) with frozen shoulder, bilateral normal vasoconstrictor responses were obtained. In the remaining 16 patients, responses were absent either unilaterally or bilaterally.

When the 22 patients with frozen shoulder who showed a symmetrical normal response were compared with 16 who showed abnormal responses (Table 2), a statistically significant association ($\chi^2=6.43$, $P<0.02$) was found between asymmetry of response and the persistence of pain in the joint. The two groups did not differ significantly in duration of symptoms, range of shoulder abduction or range of cervical spine lateral flexion.

In all the patients with frozen shoulder and controls, normal vasoconstrictor responses were obtained on both thumbs. The mean $TcPO_2$ in all the subjects fell within previously derived normal ranges (37-87 mmHg)[6]. In the patients, there was no statistically significant difference in $TcPO_2$ ($P>0.05$) between the affected and unaffected shoulder.

Discussion

Clinical tests of autonomic function include the Valsalva response, variations of the RR interval with hyperventilation, heart-rate response to standing and sustained hand grip[2]. All of these tests identify diffuse autonomic failure, but not focal or regional abnormalities in peripheral nerves. Assessment of skin vasomotor reflexes to various stimuli provides a method whereby such focal abnormalities can be detected. LDF may be used to detect such vasomotor reflexes at different sites in frozen shoulder. Reduction of cutaneous blood flow in response to test stimuli including inspiration/expiration provides an index of arteriolar tone, which is determined by sympathetic nerve activity.

We have shown an abnormal vasoconstrictor response in the skin over the shoulder of 42% of patients with frozen shoulder which was not detected in 10 healthy volunteer controls. This finding, combined with our observation that $TcPO_2$ was normal in the patients with frozen shoulder suggests that the abnormality of vasoconstrictor response detected by LDF was not the result of hypoperfusion at these sites but of some local autonomic dysfunction.

Evidence to support a role for autonomic dysfunction in the aetiology of frozen shoulder includes an association between frozen shoulder and clinical, radiological and thermographic features of cervical spine disease[6]. It has been suggested that chronic irritation of sympathetic fibres in ventral cervical nerve roots might alter the vascular supply to the shoulder and result in atrophic changes in the perivascular tissues[7]. The question as to whether this autonomic dysfunction might be related to the aetiology of frozen shoulder or merely a sequel to the condition is unclear. The most significant difference between the patients in this study who had normal and abnormal responses was the presence of pain. This difference suggests that the autonomic dysfunction was a result of pain *per se* rather than a cause or consequence of frozen shoulder. This was a static study and no measurements were made to assess the effects of therapy. Nor was it possible to examine the evolution of this condition.

The results of this limited study suggest that LDF together with the $TcPO_2$ electrode may provide an easy, non-invasive and simple method for the assessment of local autonomic response in the skin microcirculation. Their use in patients with frozen shoulder has revealed hitherto unreported abnormalities of autonomic function. The role of these abnormalities in the aetiology of frozen shoulder requires further clarification.

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