# Monitoring Intraspinal and Spinal Cord Perfusion Pressure in Acute Spinal Cord Injury

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## Introduction

We present a technique for monitoring intraspinal pressure (ISP) and spinal cord perfusion pressure (SCPP) after traumatic spinal cord injury (TSCI) [1], analogous to monitoring ICP and CPP after brain injury.

## Methods

A pressure probe was placed intradurally at the injury site in 18 patients with severe (AIS A-C) TSCI. Video 1 shows how the probe is tunnelled and Video 2 how it is placed intradurally.

Movie

Movie

SCPP = MAP - ISP, spinal cord vascular reactivity at injury site (sPRx) = correlation coefficient between mean ISP & MAP, spinal pressure-volume compensatory reserve (sRAP) = correlation coefficient between mean ISP & ISP pulse amplitude.

## Results

There were no procedure-related complications. ISP at the injury site was higher than intradural pressure below or extradural pressure [FIG. 1].

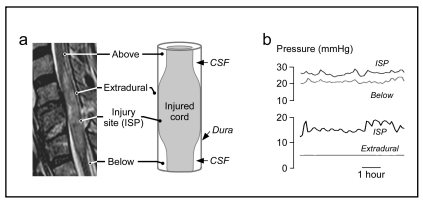


*FIG. 1. Four compartment model. a. MR scan and corresponding schematic showing four compartments: CSF above injury, injury site, CSF below injury, extradural. b. Simultaneous pressure recordings from injury site (ISP) vs. below and ISP vs. extradural.*

Intraparenchymal and subdural ISPs had similar amplitudes at the injury site [FIG.2] [2].

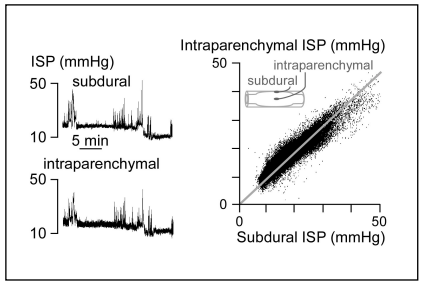


*FIG. 2. Intraparenchymal vs. subdural ISP. (left) Corresponding intraparenchymal vs. subdural ISP signals at the injury site. (right) Plot of intraparenchymal vs. subdural ISP.*

sRAP increased with decreasing SCPP (indicating reduced reserve) [FIG. 3a]. The relationship between sPRx and SCPP was U-shaped, indicating overall optimum SCPP (SCPPopt) at 90 mmHg, with marked inter-patient

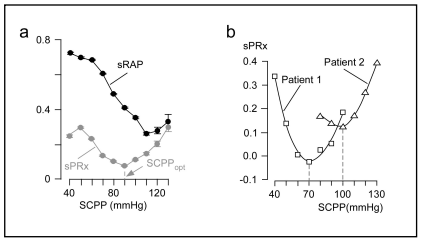


*FIG. 3. sRAP and sPRx. a. sRAP and sPRx vs. SCPP in 18 patients with TSCI. b. sPRx vs. SCPP for individual patients.*

Changing paCO2, increasing sevoflurane and giving mannitol did not alter SCPP. Increasing the dose of inotropes cause an increase in SCPP [FIG. 4].

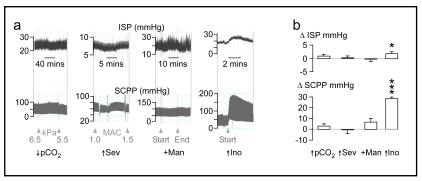


*FIG. 4. Intervening to alter ISP and SCPP. a. Effect of reducing paCO2 (49 to 41 torr), increasing sevoflurane (1.0 to 1.5 MAC), infusing 100 mL 20 % mannitol and increasing inotropes on ISP and SCPP. b. Data summary. Mean +/- SEM, * P<0.05, ** P<0.01.*

Laminectomy was potentially detrimental by exposing the swollen cord to compression forces applied to skin [FIG. 5].

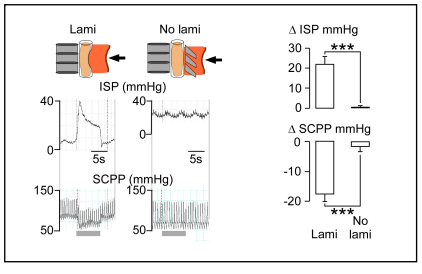


*FIG. 5. Wound compression in laminectomised and non-laminectomised patients. (left) Schematic and ISP and SCPP signals. (right) Data summary. Mean +/- SEM. *** P<0.001*

By intervening to increase SCPP, we could increase the amplitude of MEPs recorded from below or just above the injury [FIG. 6].

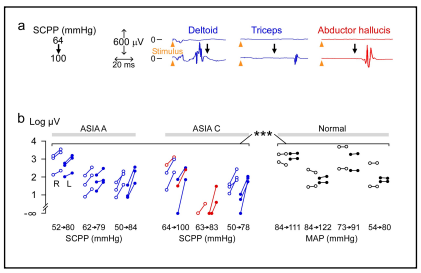


*FIG. 6. Increasing SCPP increases MEP amplitude. a. MEPs in a patient with cervical ASIA C TSCI at SCPP 64 and 100 mmHg. b. MEPs recorded at low vs. high SCPP (6 TSCI patients) and at low vs. high MAP (4 normal subjects). Points represent different muscles. Muscles below (red) and just above (blue) injury. * P<0.05, ** P<0.01, *** P<0.001.*

In cervical ASIA C patients, higher SCPP correlated with increased limb motor score and, in some patients, the sensory level was lowered by increasing SCPP [FIG. 7].

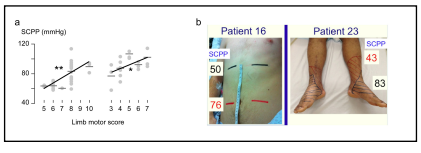


*FIG. 7. Increasing SCPP improves neurological function. a. SCPP vs. total limb motor score (0-16) for two ASIA C patients with cervical TSCI. r=0.65 (left), 0.48 (right). Points are neurological assessments. * P<0.05, ** P<0.01. b. Increasing SCPP lowers the sensory level in two patients.*

## Conclusions

1. After TSCI, ISP at the injury site can be measured safely in ICU and can be used to guide manageent.
2. Subdural ISP is the same as intraparenchymal ISP.
3. Ischaemia (low SCPP) and hyperaemia (high SCPP) may both be detrimental. SCPPopt varies amongst TSCI patients.
4. Increasing the dose of inotropes can be used to increase SCPP.
5. Laminectomy allows external forces applied to the skin to be transmitted to the spinal cord.
6. Optimising SCPP may improve outcome (increase in MEP amplitude, improved limb motor score, lowering of sensory level).

## References

1. Werndle MC et al. Monitoring of spinal cord perfusion pressure in acute spinal cord injury. *Crit Care Med* 2014;42:646-55.
2. Phang I, Papadopoulos MC. Intraspinal pressure monitoring in a patient with spinal cord injury reveals different intradural compartments. *Neurocrit Care* 2015 [EPub ahead of print].
3. Phang I et al. Expansion duroplasty improves intraspinal pressure, spinal cord perfusion pressure and vascular pressure reactivity index in patients with traumatic spinal cord injury. *J Neurotrauma* 2015;32:865-74.