

# Repeated sensor use for regional cerebral oxygenation measurements by near-infrared spectroscopy: a technical report

Paolo Ancona, Christopher T Eyeington, Salvatore L Cutuli, Neil J Glassford, Glenn M Eastwood and Rinaldo Bellomo

Near-infrared spectroscopy (NIRS) is a non-invasive tool for continuous, real-time monitoring of tissue oxygen saturation ( $Sto_2$ ).<sup>1</sup> It consists of an adhesive sensor pad, in which a light source and photodetectors are embedded, and a console for signal analysis, recording and display. NIRS has been used to assess cerebral  $Sto_2$  ( $Stco_2$ ) through the placement of a pair of sensors on patients — one sensor on each side of the forehead.<sup>2</sup> Due to the high correlation between  $Stco_2$  and the jugular bulb venous oxygen saturation measurements,<sup>2,3</sup> NIRS has been extensively used when patients are at an increased risk of brain hypoperfusion.<sup>4-11</sup>  $Stco_2$  values are influenced by physiologic variables and therapeutic interventions<sup>1-2,4</sup> which imply intra- and interindividual variability of the value observed. For this reason, clinical  $Stco_2$  assessment focuses on the change in value and observed trends rather than a single absolute value. Assessment of such trends over time would be desirable but expensive due to the cost of sensors. However, to our knowledge, no study has assessed whether there is a change in  $Stco_2$  with repeated use of a single NIRS sensor. Accordingly, we conducted an observational study in human volunteers to evaluate change in daily  $Stco_2$  measurements with repeated use of the same sensors in a cohort of healthy volunteers.

## Methods

Ethics approval was obtained through the Human Research Ethics Committee (LNR/15/Austin/468) at Austin Health, the site of the study. A convenience sample of 13 healthy adult volunteers was enrolled into a prospective, observational study between May and August 2017. A pair of O3 sensors (Masimo Corporation, Irvine, CA, USA) were symmetrically applied on the forehead of each participant for 5 minutes daily, and  $Stco_2$  was recorded by a console (Root, Masimo Corporation, Irvine, CA, USA). Participants were divided in three groups: Group A had five participants and Groups B and C had four participants each. Daily  $Stco_2$  was recorded in Groups A and B for 5 consecutive days by two pairs of sensors, each reused within the same group ("new sensor" [NS] period; sensor age, 1–5 days). Two days

## ABSTRACT

**Objective:** Near-infrared spectroscopy (NIRS) has been used in clinical practice to assess regional cerebral tissue oxygen saturation ( $Stco_2$ ). There is no evidence whether repeated use of the same sensor affects  $Stco_2$  measurements. We aimed to assess whether there was a significant systematic decrease or increase in  $Stco_2$  when NIRS sensors were reused.

**Design:** Participants were divided into three groups (A, B and C).  $Stco_2$  was recorded over 5 minutes daily for 5 days in Groups A and B ("new-sensor" [NS] period; sensor age, 1–5 days) and in Groups A and C, with the sensor previously used for A ("extended-use" [EU] period; sensor age, 6–10 days).

**Setting:** Single-centre, university hospital, intensive care unit.

**Participants:** Healthy volunteers.

**Main outcome measures:**  $Stco_2$  change within and between study periods.

**Results:** In 13 participants (9 male; median age, 30 years), the range of median  $Stco_2$  values per day was 65–72%. In the NS period, there were no changes in right-sided  $Stco_2$ , and left-sided  $Stco_2$  showed no systematic or progressive patterns of increase or decrease when comparing Day 1 with subsequent days. There were no differences when comparing Day 1 with subsequent days (up to Day 10) in the EU period or between the NS and EU periods for left or right  $Stco_2$ .

**Conclusions:** Repeated use of NIRS sensors measured  $Stco_2$  in different individuals for up to 10 days. There were no significant, systematic, persistent or progressive changes in  $Stco_2$  with extended use over time. Our findings suggest that  $Stco_2$  does not change with sensor reuse for up to 10 days.

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## TECHNICAL NOTE

afterwards,  $Stco_2$  was recorded in Groups A and C daily for 5 consecutive days by the sensors previously used in Group A ("extended use" [EU] sensor period; sensor age, 6–10 days). Sensors were cleaned before and after use. Pooled data from left and right side were analysed to assess for changes within the NS and EU periods and between these study periods. For both left and right temporal  $Stco_2$  measurements, a two-sample Wilcoxon matched-pairs signed-rank test was used to compare median  $Stco_2$  of Day 1 with each consecutive day, in both NS and EU periods. For all  $Stco_2$  measurements, the assessment between periods was performed by comparing  $Stco_2$  of Day 1 of each period. Statistical analysis was performed using Stata 14 (StataCorp, College Station, TX, USA) and, due to the high number of comparisons (> 10 000 pairs), statistical significance was taken as  $P < 0.01$  (two-tailed)

### Results

We recorded over 10 000 paired  $Stco_2$  measurements in 13 healthy volunteers, of which nine were males (median age, 30 years; interquartile range [IQR], 29–33 years; weight, 79 kg; IQR, 65–82 kg; skin type, Fitzpatrick III or less). No participants took prescribed medication and there was one current smoker. The range of median values per day was 65–72%. The NS Day 1 median  $Stco_2$  values were 70% and 66% in the left and right, respectively. In the NS period, there were no differences in right-sided  $Stco_2$  when comparing Day 1 with subsequent days. When considering left  $Stco_2$ , the NS period showed non-significant fluctuation

between Day 1 and Day 2 ( $Stco_2$ , -4%;  $P = 0.02$ ) and Day 4 ( $Stco_2$ , -4%,  $P = 0.03$ ), but not between Day 1 and Day 3 or Day 5 (Table 1). There were no such differences when comparing Day 1 with subsequent days (up to Day 10) in the EU period or between the NS and EU period for either left or right  $Stco_2$  (Table 1 and Table 2). The trend of NIRS for each subject in the two study periods is displayed in Figure 1 and Figure 2.

### Discussion

We conducted a prospective observational study in healthy volunteers to assess whether there was a significant change in  $Stco_2$  when NIRS sensors were reused in different patients over time. There were few non-significant differences in the left  $Stco_2$  in the NS period not replicated in the right. Furthermore, there were no fluctuations in the recorded  $Stco_2$  in the EU period nor between study periods in either left or right  $Stco_2$ . Our findings suggest that  $Stco_2$  does not systematically or progressively increase or decrease with extended sensor use for up to 10 days. To the best of our knowledge, this is the first study that has assessed for changes in the  $Stco_2$  of repeated measurements in different participants for a prolonged period of time. Its findings imply that extended use of NIRS sensors for  $Stco_2$  monitoring is likely acceptable for up to 10 days. We acknowledge that O3 sensors are licensed for single-person use and that an off-label use could affect performance of the tool. However, our study suggests that off-label use may be acceptable for trend determination over extended periods.

**Table 1. Median cerebral oxygenation change over time in new sensor and extended use periods**

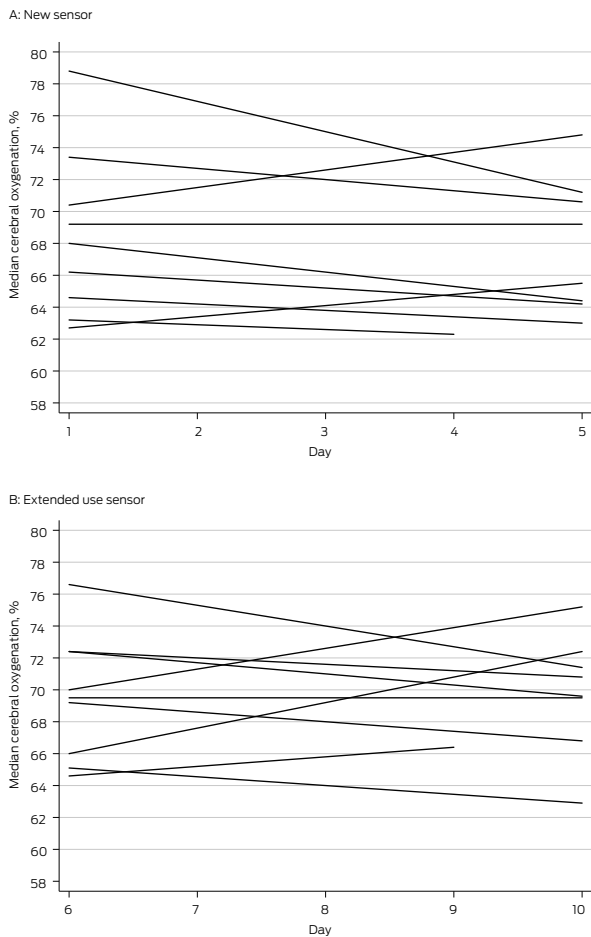
Sensor period	Cerebral oxygenation									
	%	%	<i>P</i>	%	<i>P</i>	%	<i>P</i>	%	<i>P</i>	
	Day 1 <i>n</i> = 9	Day 2 <i>n</i> = 9		Day 3 <i>n</i> = 9		Day 4 <i>n</i> = 9		Day 5 <i>n</i> = 8		
New sensor										
Left	70%	66%	0.02	65%	0.15	66%	0.03	68%	0.21	
Right	66%	71%	0.68	67%	0.10	65%	0.04	66%	0.18	
	Day 6 <i>n</i> = 9	Day 7 <i>n</i> = 9		Day 8 <i>n</i> = 9		Day 9 <i>n</i> = 9		Day 10 <i>n</i> = 8		
Extended use										
Left	71%	68%	0.28	69%	0.48	72%	1	71%	0.33	
Right	67%	68%	0.23	65%	0.86	71%	0.09	71%	0.13	

## TECHNICAL NOTE

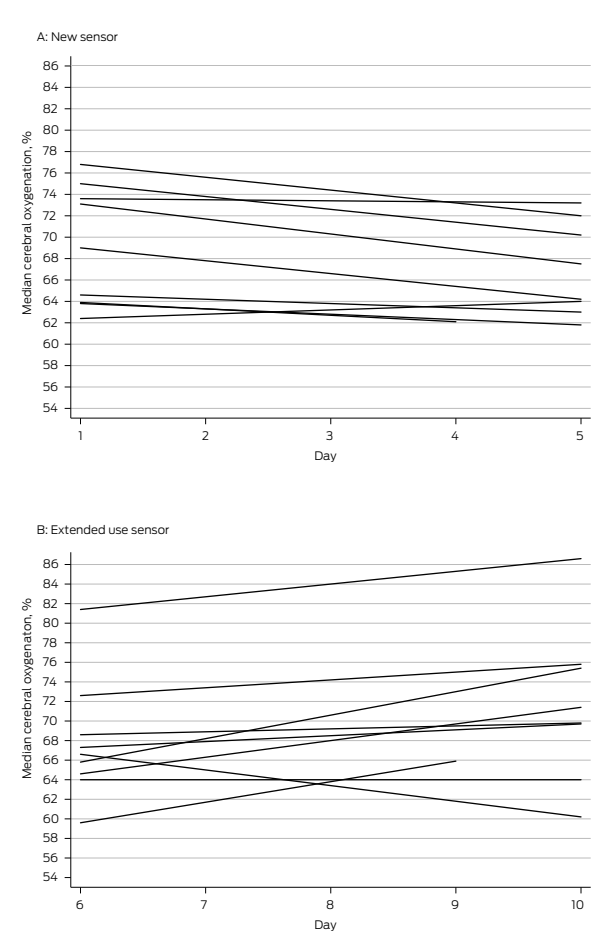
**Table 2. Comparison of median cerebral oxygenation in new sensor and extended use periods**

Hemisphere	Cerebral oxygenation									
	Day 1 v 6 <i>n</i> = 18		Day 2 v 7 <i>n</i> = 18		Day 3 v 8 <i>n</i> = 18		Day 4 v 9 <i>n</i> = 18		Day 5 v 10 <i>n</i> = 16	
Comparison	%	<i>P</i>	%	<i>P</i>	%	<i>P</i>	%	<i>P</i>	%	<i>P</i>
Left										
New	70%		66%		65%		66%		68%	
Extended	71%	0.77	68%	0.21	69%	0.31	72%	0.26	71%	0.67
Right										
New	66%		68%		65%		71%		71%	
Extended	67%	0.68	68%	0.95	65%	0.81	71%	0.08	71%	0.32

**Figure 1. Line of best fit of the left median cerebral oxygenation per participant over time**



**Figure 2. Line of best fit of the right median cerebral oxygenation per participant over time**



## Conclusions

Repeated use of NIRS sensors measured  $Stco_2$  in different individuals for up to 10 days. The range of median values per day was 65–72%. There were no significant, systematic, persistent or progressive changes in  $Stco_2$  with extended use over time. Our findings suggest that  $Stco_2$  does not change in extended use of such sensors for up to 10 days.

## Competing interests

None declared.

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