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# Endovascular aortic repair reduces gluteal oxygenation

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## Abstract

**Background:** Provoked gluteal claudication is a known risk after endovascular aortic repair (EVAR). Lowered gluteal muscle oxygenation ( $S_{gm}O_2$ ) may be demonstrated by near-infrared spectroscopy (NIRS).

**Purpose:** To evaluate NIRS-determined  $S_{gm}O_2$  in EVAR patients.

**Material and Methods:** NIRS-determined  $S_{gm}O_2$  was used in an observational study design ( $n = 17$ ). From the ambulatory setting, seven EVAR patients were included with reported gluteal claudication from medical records. In 10 patients scheduled for EVAR,  $S_{gm}O_2$  was measured before and after the procedure. NIRS sensors were applied bilaterally on the gluteal region. Treadmill walking (12% incline, 2.4 km/h) was introduced to stress gluteal muscles.

**Results:** A reduced  $S_{gm}O_2$  with regional side difference ( $P < 0.05$ ) was noted in all 10 patients following EVAR and four reported gluteal claudication. In patients with gluteal claudication ( $n = 7$ ), treadmill decreased  $S_{gm}O_2$ . The time to recover the  $S_{gm}O_2$  was prolonged for tissue exposed to occluded hypogastric artery (median = 512 s, range = 73–1207 s vs. median = 137, range = 0–643 s;  $P = 0.046$ ).

**Conclusions:** EVAR affects gluteal muscle oxygenation. NIRS could be used to assess whether gluteal claudication is related to lowered  $S_{gm}O_2$ .

## Keywords

Aorto-iliac aneurysm, endovascular, gluteal claudication, near-infrared spectroscopy, gluteal muscle oxygenation

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## Introduction

Abdominal aortic aneurysms may involve widened iliac artery (1–4); in endovascular aortic repair (EVAR), the blood flow distribution may change when revascularization affects the hypogastric arteries (5–7). While unilateral occlusion in most cases is without clinical major complications (8), lowered blood supply to pelvic region could provoke impotence (9,10). In addition, gluteal claudication may arise after EVAR (9,11). Gluteal claudication is considered related to limited  $O_2$  supply to gluteal muscles. This could be assessed non-invasively by near-infrared spectroscopy (NIRS) (12–15). Such also determines changes in tissue oxygenation, e.g. in brain (16,17) and in muscle (18,19) for healthy individuals and for patients.

The use of NIRS is reported in patients undergoing open surgery for peripheral arterial disease (20) and abdominal aortic aneurysms (17). Importantly, NIRS assessed intraoperative arterial ischemia at the buttock level in abdominal aortic aneurysm patients exposed to open surgery (12–14) or endovascular repair (15). After

open surgery that involved ligation of the hypogastric artery, NIRS was applied to the buttock to evaluate gluteal muscle oxygenation ( $S_{gm}O_2$ ) during a treadmill test (13). This decreased  $S_{gm}O_2$  and importantly prolonged time to recover oxygenation associated to occurrence of gluteal claudication. As endovascular procedures may influence vessels other than those intended for primary treatment, we speculated whether  $S_{gm}O_2$  would change by EVAR.

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In the present study, we applied NIRS to determine  $S_{gm}O_2$  in EVAR patients. Patients underwent a treadmill test to stress gluteal muscles.

## Material and Methods

Seventeen EVAR patients were included after they provided verbal and written consent as approved by the local ethics committee (H-3-2011-104). Seven patients were recruited at their annual postoperative follow-up where gluteal claudication was reported (group A). Ten patients were enrolled at a preoperative visit as they attended the clinic ahead of elective EVAR planned to involve the hypogastric artery (group B). None had symptoms of lower limb ischemia and ankle-brachial-index was  $> 0.9$  in all patients.

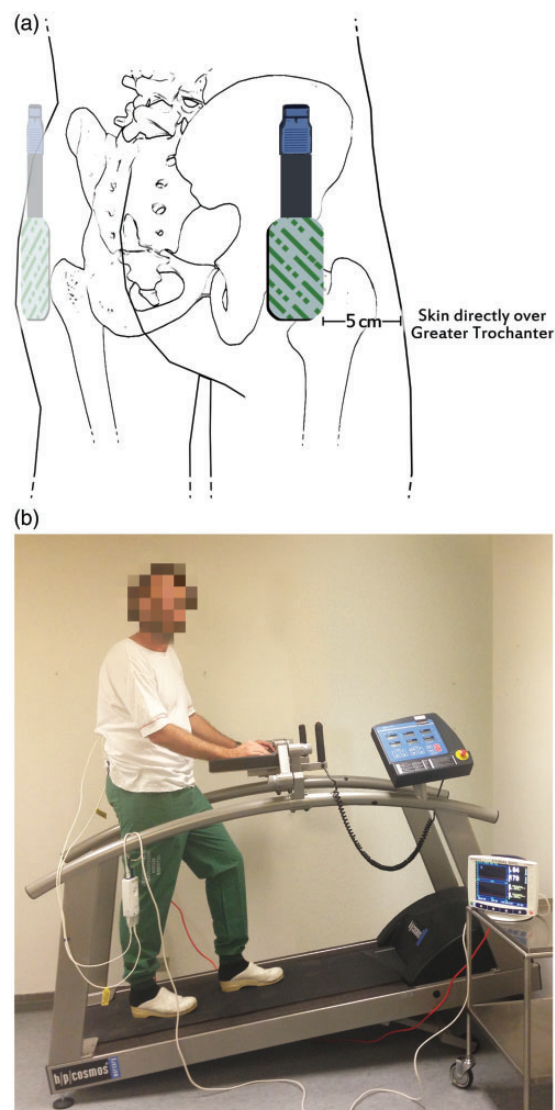
The EVAR procedures were performed under general anesthesia and followed local guidelines. A Zenith stent graft (Cook Inc., Bloomington, IN, USA) was deployed under fluoroscopy. Macro coils (Cook Inc., Bloomington, IN, USA) or an Amplatzer vascular plug (AGA Medical Corp, Plymouth, MN, USA) occluded the hypogastric artery. Branched iliac stent graft was avoided.

### Near-infrared spectroscopy

We applied INVOS-5100 (Somanetics, Troy, MI, USA) that uses two light detectors and one light-emitting diode to transmit light at two wavelengths (730 and 810 nm). Tissue oxygenation is the ratio between oxygenated and deoxygenated hemoglobin. Since the initial publication in the last century (19), NIRS is well-established; a review reported the relevance of NIRS in the clinical setting (17). If muscle oxygenation is a target of interest, NIRS is highly sensitive (18). The NIRS probes were attached in a vertical orientation on the gluteal region 5 cm posterior to the landmark of the greater trochanter of the femur (Fig. 1a). Corresponding to the NIRS sensors position at the gluteal region, the thickness of cutaneous and subcutaneous tissue was determined using the CTA images.

### Treadmill

A treadmill test (H/P/Cosmos Sport and Medical, Mercury, Nussdorf-Traunstein, Germany) stressed gluteal muscle. Baseline values were collected before exercise, which was initiated at 2.4 km/h with a 12% inclination and continued until onset of gluteal pain or when patient fatigue was reported. In patients with known gluteal claudication, treadmill walking was performed at a planned follow-up visit at least six months after the EVAR procedure. In patients scheduled for EVAR, treadmill walking was performed the day before surgery. Postoperatively, the treadmill test was done before discharge took place. During and after the treadmill test,  $S_{gm}O_2$  was recorded.



**Fig. 1.** (a) The sensors were applied 5 cm behind the bony prominence of the greater trochanter of the femoral bone in a vertical orientation. (b) The laboratory treadmill setup. The treadmill was set with an incline of 12% and a speed of 2.4 km/h. The INVOS-5100 was placed on a table next and continuously monitoring both gluteal sides.

After exercise, NIRS recordings continued for up to 10 min into recovery (Fig. 1b). A  $S_{gm}O_2$  recovery time was determined (Fig. 2). If data at the end of exercise were above baseline, recovery time was set to zero. Patients acted as their own control. A cut-off value of 240 s was used to determine sensitivity and specificity (12). A receiver operating characteristic (ROC) curve analysis was performed to find the optimal cut-off value.

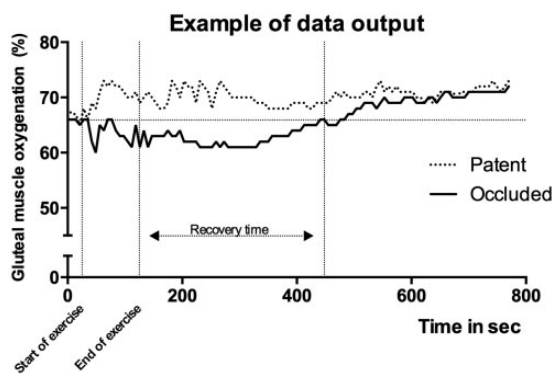
### Data processing and statistics

Mean  $\pm$  standard deviation (SD) summarized continuous variables with symmetric distribution. Median (range)

was used for non-parametric distributions. Mann–Whitney U and Wilcoxon signed ranks tests were used to compare recovery times and the NIRS response, both over time and between groups. Statistical calculations were done by IBM SPSS Statistics 20 (SPSS Inc, Chicago, IL, USA). Figures were printed in GraphPad Prism 5.0 software (GraphPad Software, San Diego, CA, USA). The level of statistical significance was  $P < 0.05$ .

## Results

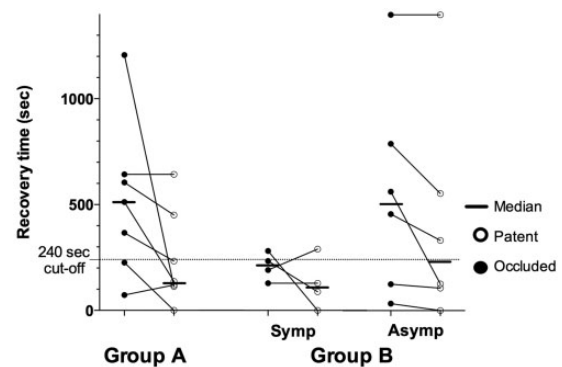
Demographics are reported in Table 1. All were men (age range = 62–78 years). Major cardiac risk factors included smoking, hypertension, and diabetes.



**Fig. 2.** Example of data from a patient examined after EVAR. The two vertical lines to the left (start of exercise and end of exercise) divides the data into the three subcategories: baseline; exercise; and recovery. A dotted horizontal line is placed at the mean values of the baseline (occluded) to mark the recovery time. In this case, the recovery time of the patent side is null and 281 s on the occluded side. This patient had gluteal claudication.

The treadmill values of group A are reported in Fig. 3. Exercise decreased  $S_{gmO_2}$ . The recovery time of the occluded side and the patent side were 512 s (range = 73–1207) and 137 s (range = 0–643), respectively ( $P = 0.046$ , Wilcoxon signed ranks test; Fig. 3). Gluteal claudication sensitivity and specificity were both 71%. The cut-off value for use of NIRS as a diagnostic test proved to be fair without an effect of different cut-off values (Fig. 3).

Before EVAR, in group B  $S_{gmO_2}$  were similar when comparing left and right gluteal regions (Fig. 4). When the stent graft was in place with hypogastric artery coverage,  $S_{gmO_2}$  decreased. Importantly, when gluteal regions exposed to occluded versus patent hypogastric artery were compared,  $S_{gmO_2}$  differed significantly ( $P = 0.045$ , Wilcoxon signed rank test). The distance



**Fig. 3.** Recovery times from each patient of the two groups. Each circle represents one gluteal side. Two circles and a connecting line represent one patient. The dotted vertical line indicates the 240-s cut-off value. ROC curve analysis did not suggest a better cut-off value.

**Table 1.** Patient demographics.

	All patients (n=17)	EVAR patients at annual follow-up (n = 7)	EVAR patients at elective surgery (n = 10)
Gender (M:F)	17/0	7/0	10/0
Age (years)	69 (62–78)	68 (62–75)	73 (64–78)
Smoker* (Yes/No)	14/3	6/1	8/2
Diabetes (Yes/No)	4/13	1/6	3/7
TCl, Stroke (Yes/No)	2/15	0/7	2/8
Hypertension (Yes/No)	11/6	3/4	8/2
Cardiac morbidity† (Yes/No)	13/4	5/2	8/2
Pulmonary morbidity†	No	No	No
ASA class 1 and 2 (n)	6	2	4
ASA class 3 and 4 (n)	11	5	6

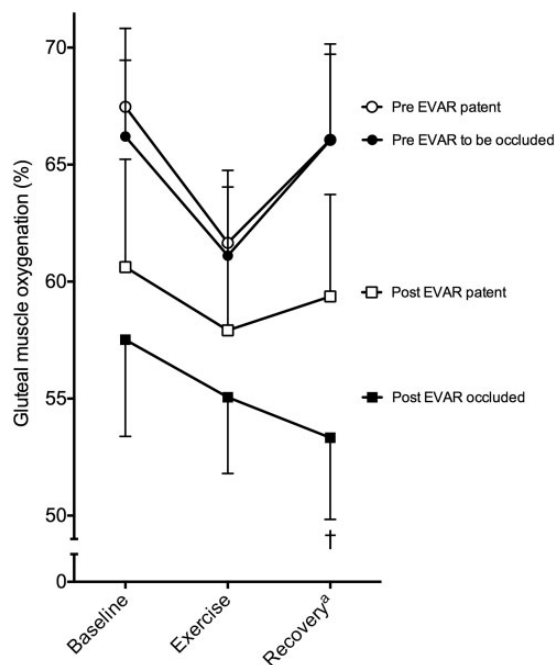
Values are presented as n. Age is presented as median (range).

EVAR patients at annual follow-up are those who were included at their clinical check after EVAR procedures were done. The other group represents patients who were scheduled for elective EVAR.

\*Current or history of smoking.

†Cardiac and pulmonary morbidity defines all treatment required conditions.

ASA, American Society of Anesthesiologist score (8).



**Fig. 4.** Gluteal muscle oxygenation at baseline, during exercise, and in the recovery period after exercise in patients treated with an EVAR that resulted in occlusion of one hypogastric artery. Patients were tested one day before and within days after the EVAR procedure (second or third day). Variables are presented in means and the included error bars are SEM for better graphical clarity. <sup>†</sup>A significant difference ( $P < 0.05$ ) in recovery values between patent and occluded side after EVAR. <sup>3</sup>Recovery values are for the first 300 s after the end of exercise for comparison; 300 s was available on all patients.

between the NIRS sensor and superficial layer of gluteal muscle was 18 mm (range = 10–36 mm) as measured from preoperative CTA images. Four of ten patients (40%) reported gluteal claudication after EVAR.

## Discussion

This explorative observational study indicated that gluteal oxygenation ( $S_{gm}O_2$ ) as assessed by NIRS may decrease in EVAR. In patients who reported gluteal claudication, we found: (i) pronounced exercise-induced reduction in  $S_{gm}O_2$ ; and (ii) prolonged time for reoxygenation of the gluteal region. These findings support a link between gluteal claudication and limited regional  $O_2$  supply; thus, NIRS may aid in determining whether regional tissue oxygenation is threatened.

Endovascular procedures may influence vessels other than those targeted for treatment due to collaterals and recruitment from the vicinity of nearby vascular beds. The hypogastric artery may deliberately be covered by a stent graft in a planned EVAR session. Collateral blood flow is traditionally considered to supplement regional demand for  $O_2$  and that collateral

branches develop over time. Such collateral blood vessel may originate from the ipsilateral iliac artery, ipsilateral profound femoral artery, contralateral hypogastric artery, the inferior mesenteric artery, and lumbar arteries (21–23). The ipsilateral external iliac artery and profound femoral artery are the major collateral arteries while the contralateral hypogastric artery is less engaged. Alterations in the collateral blood flow occur after the stent graft has been placed in the iliac arteries (21).

Symptoms from the gluteal regions are reported regularly in EVAR. Gluteal claudication covers fatigue, discomfort, or pain. This may arise with intense activity of the gluteal muscles and is a challenge since arterial stenosis limits regional blood supply. In the leg, muscle activity may cause lower leg claudication. Considering the frequent presence of limb claudication due to peripheral artery disease, gluteal claudication is a rare condition (24). While clinicians usually rely on patient reports on muscle pain, NIRS can assess skeletal muscle  $O_2$  delivery and utilization without the use of expensive or invasive procedures (18). When patients report limb claudication symptoms, NIRS-determined oxygenation is very closely related to saturations during arterial occlusion (25).

This study underscores that EVAR may influence pelvic circulation. Importantly, a drop in regional oxygenation may not be compensated. Thus, when comparing regions with the occluded versus patent hypogastric artery for patients with gluteal claudication, the recovery time was severely prolonged. In addition,  $S_{gm}O_2$  on the patent side was also compromised. A steal phenomenon might explain such findings. To keep both hypogastric arteries, the patent side should be a priority (26,27). The current available branched iliac devices should therefore be considered. This could contribute to reducing the risk of gluteal claudication after EVAR with hypogastric involvement (28,29).

This study has some limitations. The observational study design limits the strength of the data. The small sample size influences statistical power. Skin thickness could impact the NIRS signal, but the present data showed that the gluteal muscle was in the vicinity of the NIRS probe.

In conclusion, in patients exposed to occlusion of the hypogastric artery after EVAR, gluteal oxygenation decreased. The time for reoxygenation of the gluteal region was prolonged indicating potential for critical tissue ischemia. NIRS may be a feasible add-on monitoring device for EVAR patients.

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