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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 ($S_{gm}\text{O}_2$) may be demonstrated by near-infrared spectroscopy (NIRS).

**Purpose:** To evaluate NIRS-determined $S_{gm}\text{O}_2$ in EVAR patients.

**Material and Methods:** NIRS-determined $S_{gm}\text{O}_2$ 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, $S_{gm}\text{O}_2$ 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 $S_{gm}\text{O}_2$ 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 $S_{gm}\text{O}_2$. The time to recover the $S_{gm}\text{O}_2$ 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 $S_{gm}\text{O}_2$.

**Keywords**

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

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 ($S_{gm}\text{O}_2$) during a treadmill test (13). This decreased $S_{gm}\text{O}_2$ 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 $S_{gm}\text{O}_2$ would change by EVAR.

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In the present study, we applied NIRS to determine $S_{gm,O2}$ 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, $S_{gm,O2}$ was recorded.

After exercise, NIRS recordings continued for up to 10 min into recovery (Fig. 1b). A $S_{gm,O2}$ 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 ± 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.

|                         | 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                                      |
| TCI, 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).
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 ($S_{gmO2}$) may decrease in EVAR. In patients who reported gluteal claudication, we found: (i) pronounced exercise-induced reduction in $S_{gmO2}$; 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, $S_{gmO2}$ 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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References
1. Hinchliffe R, Alric P, Rose D, et al. Comparison of morphologic features of intact and ruptured aneurysms of infrarenal abdominal aorta. J Vasc Surg 2003;38:88–92.
2. Ohrlander T, Dencker M, Acosta S. Morphological state as a predictor for reintervention and mortality after EVAR for AAA. Cardiovasc Interv Radiol 2012;35:1009–1015.
3. Richarsson JW, Greenfield LJ. Natural history and management of iliac aneurysms. J Vasc Surg 1988;8:165–171.
4. Chaikof EL, Brewster DC, Dalman RL, et al. SVS practice guidelines for the care of patients with an abdominal aortic aneurysm: executive summary. J Vasc Surg 2009;50:880–896.
5. Malina M, Dirven M, Sonesson B, et al. Feasibility of a branched stent graft in common iliac artery aneurysms. J Endovasc Ther 2006;13:496–500.
6. Lebas B, Galley J, Legall M, et al. Preservation of the internal iliac arteries with branched iliac stent grafts (zenith bifurcated iliac side): 5 years of experience. Am J Surg 2016;233:18–22.
7. Fatima J, Correa MP, Mendes BC, et al. Pelvic revascularization during endovascular aortic aneurysm repair. Perspect Vasc Endovasc Ther 2012;24:55–62.
8. Lin PH, Chen AY, Vij A. Hypogastric artery preservation during endovascular aortic aneurysm repair: is it important? Semin Vasc Surg 2009;22:193–200.
9. Jean-Baptiste E, Brizzi S, Bartoli M-A, et al. Pelvic ischemia and quality of life scores after interventional occlusion of the hypogastric artery in patients undergoing endovascular aortic aneurysm repair. J Vasc Surg 2014;60:40–49.
10. Farahmand P, Becquemin JP, Desgranges P, et al. Is hypogastric artery embolization during endovascular aortoiliac aneurysm repair (EVAR) innocuous and useful? Eur J Vasc Endovasc Surg 2008;35:429–435.
11. Yano OJ, Morrissey N, Eisen L, et al. Intentional internal iliac artery occlusion to facilitate endovascular repair of aortoiliac aneurysms. J Vasc Surg 2001;34:204–211.
12. Sugano N, Inoue Y, Iwai T. Evaluation of buttock claudication with hypogastric artery stump pressure measurement and near infrared spectroscopy after abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg 2003;26:45–51.
13. Bouyé P, Jacquinandi V, Picquet J, et al. Near-infrared spectroscopy and transcutaneous oxygen pressure during exercise to detect arterial ischemia at the buttock level: comparison with arteriography. J Vasc Surg 2005;41:994–999.
14. Fukui D, Urayama H, Tanaka K, et al. Use of near-infrared spectroscopic measurement at the buttocks during abdominal aortic surgery. Cire J 2002;66:1128–1131.
15. Inuzuka K, Unno N, Mitsuoka H, et al. Intraoperative monitoring of penile and buttock blood flow during endovascular abdominal aortic repair. Eur J Vasc Endovasc Surg 2006;31:359–365.
16. Madsen PL, Secher NH. Near-infrared oximetry of the brain. Prog. Neurobiol. 1999;58:541–560.
17. Nielsen HB. Systematic review of near-infrared spectroscopy determined cerebral oxygenation during non-cardiac surgery. Front Physiol 2014;5:93.
18. Jones S, Chiesa ST, Chaturvedi N, et al. Recent developments in near-infrared spectroscopy (NIRS) for the assessment of local skeletal muscle microvascular function and capacity to utilise oxygen. Artery Res 2016;16:25–33.
19. Wilson JR, Mancini DM, McCully K, et al. Noninvasive detection of skeletal muscle underperfusion with near-infrared spectroscopy in patients with heart failure. Circulation 1989;80:1668–74.
20. Vardi M, Nini A. Near-infrared spectroscopy for evaluation of peripheral vascular disease. A systematic review of literature. Eur J Vasc Endovasc Surg 2008;35:68–74.
21. Iliopoulos JI, Hermreck AS, Thomas JH, et al. Hemodynamics of the hypogastric arterial circulation. J Vasc Surg 1989;9:637–641.
22. Chait A, Moltz A, Nelson JH. The collateral arterial circulation in the pelvis. An angiographic study. Am J Roentgenol Radium Ther Nuc Med 1968;102:392–400.
23. Kawai M. Pelvic hemodynamics before and after aortoiliac vascular reconstruction: the significance of penile blood pressure. Jpn J Surg 1988;18:514–520.
24. Hirsch AT, Haskal ZJ, Hertzler NR, et al. American Association for Vascular Surgery; Society for Vascular Surgery; Society for Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; Vascular Disease Foundation ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease. Circulation 2006;113:e463–654.
25. Silva JA, Souza DUF, Ferreira DR, et al. Tissue oxygen saturation assessment during claudication symptoms in patients with peripheral arterial disease. J Vasc Bras 2015;14:311–318.
26. Unno N, Inuzuka K, Yamamoto N, et al. Preservation of pelvic circulation with hypogastric artery bypass in endovascular repair of abdominal aortic aneurysm with bilateral iliac artery aneurysms. J Vasc Surg 2006;44:1170–1175.
27. Inuzuka K, Unno N, Yamamoto N, et al. Assessment of pelvic hemodynamics during an open repair of an infrarenal abdominal aortic aneurysm. *Surg Today* 2010;40:738–744.

28. Pavlidis D, Hörmann M, Libicher M, et al. Buttock claudication after interventional occlusion of the hypogastric artery—a mid-term follow-up. *Vasc Endovascular Surg* 2012;46:236–241.

29. Taudorf M, Gronvall J, Schroeder TV, et al. Endovascular aneurysm repair treatment of aortoiliac aneurysms: can iliac branched devices prevent gluteal claudication? *J Vasc Interv Radiol JVIR* 2016;27:174–180.