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ORIGINAL ARTICLE
CAROTID DISEASE

Comparison between transradial and transfemoral access for carotid artery stenting performed by vascular surgeons

Andrea KAHLBERG, Nicola GALATI *, Benedetta MANGILI, Elena MIGLIORANZA, Claudia ANSELMI, Daniele MASCIA, Germano MELISSANO, Roberto CHIESA

Division of Vascular Surgery, IRCCS San Raffaele Scientific Institute, Vita-Salute San Raffaele University, Milan, Italy

*Corresponding author: Nicola Galati, Division of Vascular Surgery, IRCCS San Raffaele Scientific Institute, Vita-Salute San Raffaele University, via Olgettina 60, 20132 Milan, Italy. E-mail: galati.nicola@hsr.it

ABSTRACT

Background: The aim of this paper was to compare the patient characteristics, procedural details, 30-day postoperative outcomes of carotid artery stenting (CAS) performed through radial access *versus* femoral access.
Methods: This is a single-center, retrospective, non-randomized study conducted on 613 consecutive patients who underwent elective CAS between January 2015 and January 2025. Patients were divided into two groups based on access route: radial (N.=167) and femoral (N.=446). The following were considered as the primary endpoints: 1) the occurrence of one of TIA/stroke/death; and 2) the overall perioperative complications rate. Secondary endpoints included access-site complications, procedure duration, and single complication rate.
Results: No significant differences were observed between the two groups in pre/intraoperative variables, except for the rate of symptomatic carotid stenosis (radial 22% *vs.* femoral 15%, P=0.030) and the use of dual-layer stents (radial 87% *vs.* femoral 75%, P<0.001). The TIA/Stroke/death rate (radial 1.8% *vs.* femoral 4.4%, P=0.119), overall perioperative complication rate (radial 5.4% *vs.* femoral 10%, P=0.057), and access-site complications (radial 0.6% *vs.* femoral 2%, P=0.217) were comparable between groups. However, the mean procedure time was significantly shorter in the radial group (36±15 minutes *vs.* 42±18 minutes, P<0.001).
Conclusions: Percutaneous radial access in CAS procedures was more frequently performed in symptomatic patients and with the use of newer low-profile dual-layer micromesh platforms. Radial access was associated with shorter procedural times and a trend toward lower perioperative complication rates, though the latter did not reach statistical significance.

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Key words: Carotid artery diseases; Carotid stenosis; Carotid stenting; Stents; Stroke; Radial access; Transradial access; Dual-layer stent.

Carotid artery stenting (CAS) has been established as a valid option to prevent stroke associated with carotid artery stenosis.[1]

It's value as an alternative to traditional carotid endarterectomy (CEA), has been proved especially in patients at high surgical risk, or with complex anatomical conditions, such as hostile neck or high carotid bifurcation. It's also preferred in patients with prior neck surgeries, neck irradiation, or contralateral vocal cord paralysis.

Although CAS is less invasive compared to CEA and is associated with a lower peri-procedural risk of myocardial infarction and cranial nerve complications, it carries a higher potential risk for distal embolization during and immediately after the procedure. This increases the likelihood of neurological complications, resulting in a higher incidence of minor (non-disabling) strokes compared to surgery.[2-5]

CAS panorama is rapidly evolving, driven by improvements in expertise, patient selection, and above all novel techniques and technologies.[6-11]

Also, thanks to the lower profile of new-generation carotid stents, the option of transradial access (TRA) to perform CAS is becoming more viable. Transradial access also has several potential advantages, including avoiding manipulation of the aortic arch, which reduces embolization risk, and eliminating the need for the femoral route when it's unsuitable (aorto-iliac occlusive disease, TAAA, dissection, shaggy aorta, etc). It also enhances early postoperative patient mobilization.[12]

Few studies, in the past decades, have compared transfemoral access (TFA) to TRA for CAS, reporting similar clinical outcomes and adverse events between the two approaches.[13-16] Most of these studies are based on literature review, including heterogeneous cohorts. In addition, they are conducted by interventional cardiologists or radiologists, none of them including vascular surgeons.

The aim of this study is to compare the preoperative characteristics, procedural details, and early results of CAS performed in the last 10 years through TRA and TFA, based on the experience of a single high-volume center.

Materials and methods

This is a retrospective, non-randomized, single-center study including all consecutive patients who underwent elective CAS for internal carotid artery stenosis, asymptomatic and symptomatic, at our institution between January 2015 and January 2025. Indication to type of revascularization (CEA *vs.* CAS) was decided based on CEA first approach, and CAS was considered when contraindications to CEA or high surgical risks were identified: restenosis, neck irradiation, hostile neck, high carotid bifurcation, previous neck surgical access, or other severe systemic comorbidities. Patients with restenosis after a previous CAS or those requiring emergent CAS due to perioperative carotid thrombosis after CEA were excluded from the analysis.

Demographics and risk factors, intraoperative details, and outcomes (within 30 days) were collected from a computerized database and analyzed retrospectively. Data were collected and classified following the Society for Vascular Surgery (SVS) reporting standards for carotid interventions.[17] Peak systolic velocity (PSV), stenosis grade, plaque type, the anatomy of supra-aortic vessels, and contralateral carotid status were documented. The degree of stenosis was assessed *via* duplex ultrasound (DUS) according to the European Carotid Surgery Trial (ECST) classification.[18] Plaque morphology was classified according to SVS standards, with lesion severity graded as mild (=1) for light calcifications, moderate (=2) for mixed fibrous/ulcerative plaques/thin caps, and severe (=3) for multiple large calcifications or lipid/necrotic cores based on DUS and computed tomography angiography (CTA).[17] A brain CT scan was routinely performed preoperatively, while CTA or magnetic resonance angiography (MRA) was conducted in all patients to assess the aortic arch anatomy, the origin of supra-aortic vessels, and any associated aortic or supra-aortic lesions.

Intraoperative data included the access site, the necessity for predilatation or postdilatation, and the materials used (stent type, number, and size; type and use of embolic protection devices). Postoperative outcomes were recorded, including mortality, neurological complications [ipsilateral stroke, ipsilateral transient ischemic attack (TIA), major and minor strokes], and cardiac complications such as myocardial infarction, arrhythmias, and the need for inotropic support. TIA/Stroke/Death rate was analyzed. All perioperative neurological events were evaluated by an independent neurologist. Stroke severity was determined using the National Institutes of Health Stroke Scale (NIHSS), with scores of 2 to 3 for minor strokes lasting more than 24 hours but resolving within 30 days, and scores greater than 4 for major strokes lasting more than 3 days.[17]

The patients were divided into two groups based on the type of percutaneous access method used during the CAS procedure. Six patients received bilateral femoral access for both procedures.

Transradial access from the right arm was used at the operator's discretion, particularly in cases of right internal carotid artery (ICA) stenosis with an acute aortic arch (type II or type III with reverse angulation of the target vessel, as per SVS carotid intervention standards) or when a favorable subclavian-common carotid artery angle was present. Radial access was also preferred in cases of left ICA stenosis with a "bovine" arch configuration. Limitations for using a radial access are inadequate radial-to-subclavian access way (*e.g.*, CABG with RIMA, aberrant right subclavian artery, presence of an arteriovenous fistula for dialysis) or poor hand collateral circulation. For the last purpose, Allen's test was performed preoperatively by manually occluding both radial and ulnar arteries while the patient clenched the fist, followed by the release of one artery to assess palmar reperfusion, considering a five-second cut-off for adequate reperfusion.[19]

This study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure transparent and comprehensive reporting of cohort study findings.[20]

The present study followed the principles outlined in the Declaration of Helsinki and used information from a review of medical charts. Patients gave their consent for the anonymous collection of their data on the standard consent sheet provided by our institution for the use of CE (Conformitè Europëenne) approved devices. Institutional review board approval was waived for this observational retrospective study according to Italian laws.

Procedure

The procedures were performed by experienced vascular surgeons, each with a minimum of 50 lifetime CAS procedures and at least 25 CAS procedures performed annually. Dual antiplatelet therapy (DAPT) was administered before stenting by established guidelines. Patients received pretreatment for at least three days with clopidogrel (75 mg/day) or ticlopidine (500 mg/day), along with acetylsalicylic acid (100 mg/day).[3, 5, 17]

Under local anesthesia, percutaneous access was obtained *via* the common femoral or radial artery using ultrasound guidance.

At the beginning of the procedure, patients received an intravenous bolus of full-dose heparin (70 IU/kg). Selective common carotid artery (CCA) access was established using a long, flexible, hydrophilic introducer sheath (typically a 5-Fr or 6-Fr Flexor; Cook Medical, Bloomington, IN, USA) over a pre-shaped 5-Fr catheter (*e.g.*, multipurpose curve, vertebral, or V-Tek), which remained in place throughout the intervention. A distal embolic protection device (EPD), such as the SpiderFX (EV3 Endovascular Inc, Plymouth, MN, USA) or the Emboshield NAV (Abbott Vascular, Abbott Park, IL, USA), was advanced into the ICA under fluoroscopic guidance. Predilatation was performed only in cases of near-occlusive stenosis to facilitate stent placement.

Stent deployment was carried out under road-mapping guidance or by using vertebral bones as anatomical landmarks. Various self-expanding stents were used, with diameters ranging from 6 to 10 mm and lengths between 20 and 40 mm. These stents featured different designs, including cylindrical or tapered shapes, and various cell geometries such as closed-cell, open-cell, hybrid-cell, and - in 78% of the procedures (479) - were performed using dual-layer stents (DLS, Roadsaver, Terumo Corp, Tokyo, Japan and C-Guard, InspireMD, Tel Aviv, Israel). The details of the stents used are reported in Table I. Post-dilatation was performed in most cases, and intravenous atropine (0.5-1 mg) was administered if patients developed hypotension or bradycardia. A final angiographic assessment was conducted before retrieving the embolic protection devices.

For femoral access, manual compression was applied for approximately 30 minutes following sheath removal to minimize the risk of local complications. In cases of radial access, a compression dressing was immediately applied, preferably using a dedicated radial compression device (TR Band, Terumo Corp, Tokyo, Japan).

Throughout the procedure, continuous monitoring was conducted to assess neurological status, hemodynamic parameters, and activated clotting time. Routine intraoperative monitoring included electrocardiography, pulse oximetry, and intra-arterial pressure measurement *via* the sidearm of the introducer sheath to detect and promptly address hemodynamic alterations. The patient's level of consciousness, speech, and motor function were continuously assessed by having them respond to simple questions and squeeze the anaesthesiologist's hand with the contralateral hand.

TABLE I.—*Stent brand distribution.*

Variable[a]	Radial access (N.=167)	Femoral access (N.=440)
Roadsaver, Terumo Corp	141 (84%)	312 (71%)
C-Guard, InspireMD	4 (2%)	22 (5%)
Carotid WALLSTENT, Boston Scientific	6 (4%)	19 (4%)
Xact, Abbott	5 (3%)	51 (12%)
Precise, Cordis	9 (5%)	35 (8%)
Cristallo Ideale, Invamed	2 (1%)	1 (0.2%)

[a]Continuous data are presented as the means±standard deviation; categorical data are given as the counts (percentage).

Postoperative care

DAPT with acetylsalicylic acid (100 mg/day) and clopidogrel (75 mg/day) was maintained for at least 30 days. Following carotid artery stenting, indefinite oral statin therapy was recommended for all patients, unless contraindicated.

The postoperative follow-up protocol included a duplex ultrasound (DUS) examination and clinical evaluation before discharge and at 30 days. Postprocedural CTA or MRA was conducted only in the presence of cerebral adverse events.

Statistical analysis

Continuous variables were reported as mean±standard deviation, while categorical variables were expressed as absolute numbers and percentages. Differences between groups stratified by access type (radial *vs.* femoral) were assessed using Fisher's Exact Test for dichotomous variables and the Student's *t*-test for continuous variables. All tests were two-tailed, and a P value of ≤0.05 was considered statistically significant.

Results

Over a ten-year period, from 2015 to 2025, a total of 4873 open carotid interventions were performed in our center, with an average of 487 procedures per year. During the same timeframe, 704 endovascular carotid interventions were carried out, corresponding to an average of 70 cases annually. This reflects a predominance of open procedures over endovascular approaches, with an overall open-to-endo ratio of 7:1.

After applying exclusion criteria, 91 patients were excluded from the current analysis. The final study population consisted of 613 elective CAS procedures performed on 607 patients (441 males, 73%; mean age 73.1±8.1 years) between January 2015 and January 2025. TRA was used in 167 procedures (27%), while TFA was employed in 446 procedures (73%). Six patients (1%) underwent bilateral CAS in the TFA group. CAS was performed transradially on a total of 125 right ICAs (75%) and 42 left ICAs (25%). Among left ICA cases treated through TRA, 33 (78%) had a "bovine" aortic arch associated with left carotid stenosis. Additionally, 41 patients (25%) in the TRA group presented with a type III aortic arch.

A breakdown of all groups is illustrated in Table II, III. During the study period, 8 patients required emergency CAS due to perioperative carotid thrombosis immediately after CEA and were excluded from the analysis.

No significant differences were observed in demographic characteristics between patients treated through TRA and TFA (Table II). Symptomatic carotid stenoses were significantly more frequent in the TRA group as compared to the TRF group, with a statistically significant difference (N.=37 [22%] *vs.* N.=66 [15%]; P=0.03). There were no further statistically significant differences between the two groups in the characteristics of carotid stenosis (Table III).

Of the total procedures, 479 (78%) were performed using DLS, while 134 (22%) used single-layer carotid stents. The use of DLS was significantly higher in the TRA group compared to the TFA group, with a statistically significant difference (N.=145 [87%] *vs.* N.=334 [75%]; P<0.01].

The total time of CAS procedures was shorter in the TRA group than in the TFA group (36±15 minutes *vs.* 42±18 minutes; P<0.01). In 12 procedures (2%), ICA morphology such as tortuosity, coiling, or kinking prevented filter EPD advancement. Among these cases, no major neurological adverse events were recorded. Additional procedural details are summarized in Table IV.

At 30 days, no cases of mortality or cerebral hemorrhage were observed in either group. The TIA rate (TRA 1.8% *vs.* TFA 2.9%, P=0.44) and stroke rate (TRA 0% *vs.*

Table II.—*Demographics and risk factors.*

Variable[a]	Radial access (N.=167)	Femoral access (N.=440)	P
Age	73.7±8.0	74.1±7.8	0.580
Male	124 (74%)	317 (72%)	0.586
Active smoker	13 (8%)	27 (6%)	0.464
History of smoking[b]	92 (55%)	233 (53%)	0.638
Hypertension	152 (91%)	392 (89%)	0.487
Hyperlipidemia	147 (88%)	374 (85%)	0.340
Diabetes	60 (36%)	136 (31%)	0.238
Coronary artery disease	62 (37%)	150 (34%)	0.484
Chronic kidney disease[c]	18 (11%)	40 (9%)	0.528

[a]Continuous data are presented as the means±standard deviation; categorical data are given as the counts (percentage); [b]Stop smoking more than 1 year; [c]eGFR<60 mL/min

Table III.—*Characteristics of the disease.*

Variable[a]	Radial access (N.=167)	Femoral access (N.=446)	P
ICA stenosis grade (%)	77.6±8.0	76.4±7.0	0.070
Peak systolic velocity (cm/s)	332±119	327±107	0.618
Right ICA	125 (75%)	177 (40%)	0.001*
Type III aortic arch	41 (25%)	89 (20%)	0.215
"Bovine" arch configuration	39 (23%)	51 (11%)	0.001*
Contralateral ICA stenosis (%)	41.5±23.5	43.9±25.7	0.293
Controlateral ICA occlusion	7 (4%)	13 (3%)	0.428
Symptomatic stenosis	37 (22%)	66 (15%)	0.030*
Reintervention	78 (47%)	187 (42%)	0.287
Neck irradiation	30 (18%)	94 (21%)	0.393

ICA: internal carotid artery.
[a]Continuous data are presented as the means±standard deviation; categorical data are given as the counts (percentage).

Table IV.—*Procedural details.*

Variable[a]	Radial access (N.=167)	Femoral access (N.=446)	P
Double layer stent	145 (87%)	334 (75%)	0.001*
Use of embolic protection devices	164 (98%)	437 (98%)	0.860
Need of predilatation	3 (2%)	4 (1%)	0.351
Number of implanted stents	1.1±0.6	1.2±0.8	0.143
Stent length (mm)	33±9	34±4	0.058
Stent post-dilatation	159 (95%)	433 (97%)	0.256
Atropine administration	30 (18%)	71 (16%)	0.543
Duration of procedure (min)	36±15	42±18	0.0001*

[a]Continuous data are presented as the means±standard deviation; categorical data are given as the counts (percentage); *statistically significant.

Table V.—*Clinical 30-day outcomes.*

Variable[a]	Radial access (N.=167)	Femoral access (N.=446)	P
Length of stay (mean±SD)	1.8±1.0	2.1±1.3	0.766
Access complications	1 (0.6%)	9 (2.0%)	0.217
Cerebral hemorrhage	0 (0%)	0 (0%)	1
Inotropic support[b]	5 (3.0%)	17 (3.8%)	0.628
Arrhythmias	1 (0.6%)	4 (0.9%)	0.715
TIA	3 (1.8%)	13 (2.9%)	0.439
Stroke	0 (0%)	7 (1.6%)	0.198
Minor[c]	0	5 (1.1%)	0.330
Major[c]	0	2 (0.4%)	1
MI	0 (0%)	0 (0%)	1
Death	0 (0%)	0 (0%)	1
Any complications[d]	9 (5.4%)	46 (10%)	0.057
Stroke/TIA/death	3 (1.8%)	20 (4.4%)	0.119

MI: myocardial infarction; TIA: transient ischemic attack.
[a]Continuous data are presented as the means±standard deviation; categorical data are given as the counts (percentage); [b]need of drugs to increase the cardiac output in case of heart failure. In all cases, dobutamine was the drug of choice; [c]National Institutes of Health Stroke Scale
(NIHSS), minor strokes lasting more than 24 hours but resolving within 30 days, major strokes lasting more than 3 days; [d]number of patients who developed one or more complications among the ones mentioned above.

TFA 0.9%, P=0.58) were not significantly different between groups. All TIAs occurred in the setting of symptomatic stenosis. The combined TIA/stroke/death rate (TRA 1.8% *vs.* TFA 4.4%, P=0.12) was also comparable. Overall perioperative complication rate (TRA 5.4% *vs.* TFA 10%, P=0.057), and access-site complications (TRA 0.6% *vs.* TFA 2%, P=0.217) (TRA: one radial occlusion; TFA: seven pseudoaneurysms and two hemorrhages requiring multiple transfusions) were comparable between groups. Clinical 30-day outcomes are detailed in Table V.

Discussion

In our experience, the choice of percutaneous access site was mainly based on the operator's preference, and on patient's anatomical characteristics. Our clinical experience revealed no statistically significant differences between the two study groups regarding postoperative outcomes. These results are consistent with existing literature, reinforcing the concept that CAS can be performed safely and effectively using both transradial and transfemoral access routes.[15]

Transfemoral access continues to be the preferred approach for CAS, as it is the most widely adopted technique among vascular surgeons, interventional radiologists, hemodynamic cardiologists, and electrophysiologists. This is further supported by data from this study, where TFA was used in 446 out of 613 procedures (73%). This preference is largely due to their extensive experience with transfemoral access in a wide range of endovascular procedures and diagnostic interventions. The familiarity and well-established protocols associated with this method contribute to its widespread use, ensuring procedural efficiency, reliability, and ease of catheter navigation. Additionally, transfemoral access allows for the use of larger-calibre devices, which can be advantageous in complex cases requiring advanced endovascular techniques. However, despite its ease of use, TFA presents several limitations and disadvantages. It is particularly challenging and potentially hazardous in obese patients, those with an aortic aneurysm, or individuals with a high femoral bifurcation. Moreover, the incidence of both major and minor access complications remains significant following transfemoral CAS.[21]

Another drawback is the requirement for prolonged post-procedural movement restriction, which also adversely impacts patient comfort. Although femoral closure devices have been introduced to mitigate vascular access complications and reduce bed rest duration, no significant reduction in vascular complication rates has been observed compared to manual compression.[22] Furthermore, marked tortuosity or significant stenosis of the iliac artery can impair the handling of guidewires and catheters, as well as the precise deployment of stents.

Selective cannulation of the supra-aortic vessels represents one of the most technically demanding and critical aspects of CAS procedures. This task becomes particularly complex in the presence of a type III aortic arch, a "bovine" arch configuration, a tortuous brachiocephalic artery, or severely calcified aortic arch. In such cases, catheter manipulation may lead to mobilization of calcifications from the aortic arch and/or the disruption of carotid plaques, potentially resulting in cerebral embolization.

Faggioli *et al.* reported, silent cerebral embolization, assessed using diffusion-weighted magnetic resonance imaging, may occur in up to 60% of patients, affecting both the contralateral (82%) and ipsilateral (18%) hemispheres. These findings suggest that embolization is attributable not only to the stenting procedure itself but also to the cannulation process.[23] Difficult vessel cannulation and anatomically high-risk CAS are associated with an increased incidence of periprocedural stroke.[24]

Consistently, Casana *et al.* showed that postoperative mortality and neurological complication rates are associated with type III or "bovine" aortic arch morphology, irrespective of whether carotid stenosis is symptomatic or asymptomatic.[25]

Transradial access is currently recommended as the default approach for cardiac catheterization by both European and American guidelines.[26, 27] These recommendations are based on robust evidence demonstrating the superiority of TRA over TFA in terms of major bleeding, vascular complications, and all-cause mortality among patients undergoing coronary angiography and/or percutaneous coronary intervention.[28] For this reason, cardiologists have highly focused on the use of radial access also during CAS, being quite the only specialist (together with interventional radiologists) who have also published some literature reviews in the past decades.[14-16]

On the other hand, TRA access has not been extensively investigated in the context of CAS, by vascular surgeons. Current ESVS guidelines suggest that TRA should be considered as a viable alternative to TFA in case of carotid procedures, particularly in cases of hostile aorto-femoral routes.[29]

In our series, a statistically significant difference was observed in procedural duration between TRA and TFA access, favoring the former. The clinical impact of this finding remains to be clarified and is likely minimal; however, our findings differ from those previously reported in the literature. Zoltan *et al.*, for instance, did not identify significant differences in procedure duration within their patient cohort.[16] This discrepancy may be attributed to variations in operator expertise and procedural volume, as a higher annual caseload is likely to contribute to improved proficiency and reduced operative times.

Among the limitations of radial access, aside from left carotid stenosis in the absence of a "bovine" aortic arch, one may be the radial artery compatibility with introducer sheaths. In this context, the availability of DLS, which is becoming one of the "gold standards" for CAS, has solved in most cases, this concern in clinical practice, due to their lower profile.[10, 30] As a matter of facts, recent high-quality studies have demonstrated that, dual-layer stent technology may have a positive role in reducing cerebrovascular events in symptomatic and asymptomatic patients, especially in high-volume centers.[10, 31]

In contrast to other studies available in the literature, this study appears to be a comprehensive analysis conducted within a high-volume center, characterized by a standardized procedural approach and a team of highly experienced, and carefully selected operators, thereby providing a real-world perspective. Furthermore, it is noteworthy that this research was carried out exclusively by a team of vascular surgeons, ensuring a high level of specialization. The study benefits from a substantial number of cases and procedures performed over the past decade, leveraging the most advanced materials and state-of-the-art interventional techniques available.

Limitations of the study

Several limitations of this study should be considered. First, its non-randomized nature and the possibility of selection bias may impact the reliability of our results. Moreover, microembolization was not evaluated through transcranial Doppler or diffusion-weighted magnetic resonance imaging, and no post-procedural cognitive assessments were conducted.

The identification of complex anatomical characteristics was based on the operators' subjective judgment and was not confirmed by an independent core laboratory.

Despite these constraints, this study remains one of the most extensive comparative evaluations of TRA and TFA access in the setting of CAS, and probably the only retrospective single-center analysis conducted by Vascular surgeons alone.

Conclusions

During CAS, percutaneous radial access, in our experience, is more frequently used in symptomatic patients, and in conjunction with newer low-profile dual-layer stent platforms. Nevertheless, perioperative outcomes in patients undergoing CAS trough radial access were not inferior in terms of cerebrovascular events – including death, ipsilateral stroke, and TIA – when compared to transfemoral access. Additionally, radial access may be associated with shorter procedural times, and a mild reduction of overall rate of complications, despite worse clinical presentation of the patients. Future large-scale randomized studies will be necessary to validate these findings.

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Authors' contributions
Andrea Kahlberg, Nicola Galati shared first authorship. Andrea Kahlberg has given substantial contributions to the conception or the design of the manuscript; Andrea Kahlberg, Nicola Galati, Benedetta Mangili and Elena Miglioranza have given substantial contributions to acquisition, analysis, and interpretation of the data; Andrea Kahlberg, Nicola Galati and Claudia Anselmi have participated to drafting the manuscript and revised it critically. All authors read and approved the final version of the manuscript.

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