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Abstract
Keywords

Scalp arteriovenous malformations (AVMs) are rare extracranial vascular malformations. In the past, etiologies such as trauma, idiopathic, and iatrogenic have been considered.1 Traditionally, these lesions are treated by surgical excision or by combined endovascular-surgical approaches. We describe percutaneous treatment of scalp AVM, using a new liquid embolic agent, SQUID. Because of its nonadhesive property, prolonged injection and complete obliteration of scalp AVM is feasible. The cast formed is aesthetically appealing to the patient, and it may obviate the need for further surgical excision. It could be considered as the primary treatment option for patients unwilling for surgery.

Keywords
► scalp arteriovenous malformation
► ethylene vinyl alcohol copolymer
► SQUID
► percutaneous embolization

Introduction

Scalp arteriovenous malformations (AVMs) are rare extracranial vascular malformations. In the past, etiologies such as trauma, idiopathic, and iatrogenic have been considered.1 Traditionally, these lesions are treated by surgical excision or by combined endovascular-surgical approaches.2-5 Recent reports describe the treatment of scalp AVM with nonadhesive liquid embolic agent such as Onyx (Covidien/Medtronic, Irvine, California, United States).6-9 The existing literature pertains to transarterial as well as percutaneous embolization of scalp AVM. The data on percutaneous approaches are limited, and there are no reports as yet on the use of the new liquid embolic agent, SQUID (Emboflu, Switzerland) in the treatment of scalp AVM. We describe the technical details and advantages of percutaneous treatment of scalp AVM with SQUID and briefly review the existing literature on application of ethylene vinyl alcohol (EVOH) co-polymer in the treatment of this extracranial vascular malformation.

Case Description

A middle-aged man presented with complaints of bruit over the left mastoid region, which increased in severity over the last 6 months. Clinical examination revealed pulsatile soft swelling and thrill over the left mastoid region, and it was confirmed to be scalp AVM by Doppler evaluation. He was considered for definitive therapy as the bruit was troublesome. Under general anesthesia, he underwent angiographic evaluation, which revealed predominantly fistulous AVM fed by hypertrophied feeders of superficial temporal and occipital arteries and draining into ectatic superficial parieto-occipital vein. The AVM was confined to the scalp region with no communication to intracranial venous structures. Following angiography, the dilated venous sac of the AVM was accessed percutaneously using a 16G cannula under roadmap guidance from external carotid artery injection. The cannula was advanced further into the vein using a 0.035-in hydrophilic guide wire and secured with a sterile tape. A rotating hemostatic valve was attached to the hub of cannula.
to avoid back bleed. The vein was later catheterized with an Echelon (Covidien/Medtronic) microcatheter over a Traxcess (MicroVention, Tustin, California, United States) microguidewire, and the tip of the microcatheter was placed closed to the nidus. The microcatheter dead space was flushed with DMSO, and the vein was slowly occluded with 3.5 mL of SQUID 18 embolic agent over 20 minutes. Because of high flow, temporary flow arrest was obtained to form an initial cast, and subsequent embolization allowed permanent stabilization of the embolic agent. Retrograde embolization into the nidus and arterial feeders were also noted during the embolization. Check angiogram revealed complete obliteration of the fistula, and the microcatheter and cannula were removed without any complications (Fig. 1). Postprocedure, small boggy swelling was noted at the site of the AVM without any tenderness or skin discolorations. He was discharged on postprocedure day 2, and clinical and Doppler evaluation revealed no residual AVM or nodular embolic cast at 1-year follow-up.

**Discussion**

The clinical presentation of scalp AVM may vary from benign features such as pulsatile swelling and tinnitus to malignant symptoms such as life-threatening hemorrhage and scalp necrosis. The indications for treatment include recurrent or massive hemorrhage from the AVM, bothersome symptoms, or cosmetic concerns. Traditionally, the scalp AVMs have been treated by surgery that included radical surgical excision and feeding artery ligation. The surgery is often complicated by major intraoperative bleeding and the surgeon attempts to achieve hemostasis by feeding artery ligation, tourniquets, or clamps. Incomplete excision results in residual or recurrent AVMs and further complicates future surgical or endovascular management. Also, scalp reconstruction is an important consideration when the surgical defect is large.

Over the last two decades, endovascular management has been increasingly reported as the mainstay therapy or surgical adjunct in the treatment of scalp AVMs. The endovascular routes are varied and the choices of embolic agents are myriad. Tranarterial, transvenous, and percutaneous approaches with different embolic agents such as polyvinyl alcohol (PVA) particles, n-butyl cyanoacrylates (n-BCA), and EVOH copolymers are all described in the literature. The endovascular treatment is particularly attractive as it is minimally invasive and could be repeated several times to achieve adequate devascularization prior to

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**Fig. 1** Selective occipital angiogram (A) shows a scalp AVM in the mastoid region. The venous side of the AVM is accessed percutaneously by 16G (B) and a microcatheter is navigated close to the nidus under roadmap guidance (C). Following initial microcatheter angiogram (D), the AVM is embolized with SQUID embolic agent. The embolic cast (E) and obliterated AVM (F) is demonstrated.
definitive surgical excision. Direct puncture and n-butyl
cyanoacrylate embolization of scalp AVMs have been found
to be safe and effective in achieving devascularization prior
to surgery. Although complete obliteration is achievable in
certain situations, surgical resection is often performed to
avoid recurrence as well as cosmetic disfigurement due to
lumpy glue cast.\(^5,6\)

Recently, the EVOH co-polymer–based liquid embolic
agent, Onyx has been shown to be effective in the treatment
of scalp AVMs.\(^6–8\) EVOH copolymer is nonadhesive, and
hence it permits prolonged injection time without the
fear of catheter entrapment. It precipitates along the vessel wall
and slowly permeates into various nidal and venous com-
partments, and thus it can achieve higher obliteration rates
compared with n-BCA. The progress of embolization could be
assessed with repeated angiograms and the operator could
preferentially fill the residual nidus or avoid important
vascular segment by “wait and push” technique. Flow reduc-
tion is necessary to form an initial stable plug, and this is
achieved by several ways such as proximal arterial balloon
occlusion, retrograde venous balloon occlusion, coating of
selective venous tributaries followed by Onyx embolization,
and coating of venous sac or with tourniquets.\(^6–11\) Postem-
bolization, boggy swelling is evident over the embolized
AVM, which is aesthetically acceptable to patients, especially
if they wish to avoid further surgery.\(^1,2\) SQUID is a recently
introduced liquid embolic agent that has chemical composi-
tion similar to Onyx. The notable difference of SQUID from
Onyx is in the particulate size of the tantalum, which
provides radio-opacity to the embolic material. The micro-
nization of tantalum in SQUID retards its precipitation with
in the microcatheter, and thus it reduces the risk of micro-
catheter blockage, especially during prolonged injection
periods. The embolic agent has received CE approval for
the treatment of cerebral AVM, and it is currently available
in Europe and some Asian countries.

The success of endovascular treatment depends on three
factors: (1) the microcatheter tip as close as possible to
fistula as to enable optimal penetration of embolic agent
into the nidus and the venous sac; (2) adequate flow arrest
allowing stable embolic plug formation and prevent inad-
vertent pulmonary embolization; and (3) appropriate choice
of embolic agent to allow prolonged injection and avoid
catheter entrapment. Transarterial approach can be cumber-
some as the arteries are extremely tortuous and serpiginous and precludes favorable microcatheter position
close the nidus. Similarly, venous approach too can be
difficult due to the presence of sacs, ectasias, or ramifica-
tions. Moreover, these approaches need flow arrest using
balloons or tourniquets to allow stable cast formation and
prevent inadvertent migration.\(^6,8\)

There is only sparse literature on percutaneous direct
puncture Onyx embolization of scalp AVMs, and there are no
reports as yet on usefulness of SQUID in the treatment of
scalp AVMs. SQUID is available in two compositions differing
in viscosity (SQUID 12 and SQUID 18). The tantalum powder
in SQUID is micronized to avoid precipitation and catheter
clogging during prolonged injections. We percutaneously
accessed the principal draining vein distal to the nidus and
cannulated the foot of nidus using a microcatheter. A 16G
cannula allows the introduction of microcatheter and this
cannula could be safely taped onto the scalp. Flow arrest
could be achieved by taping the cannula tightly, and second-
ary veins could be compressed manually or with temporary
tourniquets during the procedure. Once stable embolic cast
is formed, flow limitation is not mandatory. Additionally, it
allows prolonged injection of embolic agent without serious
concern of the degree of reflux because, if the catheter is
entrapped, it could be cut at the puncture site and left in situ.
The limitation of this technique includes operator radiation
exposure during the vascular access; however, it is much less
compared with direct access and glue embolization as the
longer catheter length allows the operator to stay away from
the X-ray tube during embolization. Risk of blackish staining
over the skin exists, though we have not observed it in our
patient.

Conclusion

Percutaneous direct puncture embolization using SQUID is an
additional treatment option for patients with scalp AVMs. It
avoids several limitations associated with other therapeutic
options and could be considered as the primary treatment
option for patients unwilling for surgery. Long-term follow-up
and larger experience are needed to confirm these findings.

Contributions of Authors
Santhosh Kumar Kannath contributed in concept, design,
data analysis, data interpretation, manuscript prepara-
tion, and critical revision, and Jayadevan Enakshy Rajan
contributed in data analysis, data interpretation, manu-
script preparation, and critical revision.

Conflicts of Interest
The authors have no personal or financial conflict of interest to disclose.

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