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Venous Coupler in Pediatric Free Tissue Transfer: Case Series and Literature Review

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Background: Venous couplers have gained widespread acceptance as an effective, safe, and time-efficient alternative for hand-sewn anastomosis in microsurgical reconstruction. The literature on venous couplers use in pediatric free tissue transfer is scant. The purpose of this study is to present our experience with coupler-assisted venous anastomosis in young pediatric free flap reconstruction.

Methods: This is a retrospective single-center review of all children younger than 10 years old who underwent free flap reconstruction over 36-month period. The primary objective was to assess flap survival rate at 30-day postoperative period. The rate of venous thrombosis, flap take back, flap salvage, and the mean coupling time were also assessed.

Results: Four girls and 1 boy with a mean age of 7.3 ± 2.7 years (range 4–10 years) underwent 6 free flap transfers for head and neck, upper limb, and lower limb reconstructions. Microvascular anastomotic coupler system was used for 8 out of 9 performed venous anastomoses with a size ranging from 1.5 to 2.5 mm. Primary flap survival rate was 100%. None of the flaps in our series developed venous thrombosis or required flap take back for microvascular compromise (mean follow-up of 14.4 months). The mean coupling time was 7.1 minutes.

Conclusions: In the current study, venous couplers were safe and reliable in free tissue transfer in children younger than 10 years old. Future studies with larger sample size are needed to further examine the safety and efficacy of venous couplers in pediatric microsurgical anastomosis. *(Plast Reconstr Surg Glob Open 2020;8:e2647; doi: 10.1097/GOX.0000000000002647; Published online 26 February 2020.)*

INTRODUCTION

Free flap transfer has been safely performed in children to restore form and function with least morbidity yielding reliable results in cases of congenital anomalies and posttraumatic and oncologic reconstruction.[1,2] Microsurgical reconstruction in children is still challenging due to technical difficulties in flap dissection, vasospasm, and small-vessel diameter anastomosis.[1,2] Venous anastomosis is one of the most significant determinants of free flap survival as most reported flap failures were attributed to venous thrombosis.[3] Hand-sewn anastomosis remains the gold standard method for venous anastomosis despite being time-consuming and technically challenging particularly when dealing with small and thin-walled veins.[3–5] Microvascular anastomotic coupling devices (MACDs) were introduced in the 1960s and have been shown to be an effective alternative to hand-sewn anastomosis supporting the widespread of their use in venous anastomosis.[4] The volume of data demonstrating the efficacy and safety of MACD is expanding, majority of which, however, is pertaining to adult population.[6–19] The number of studies assessing their utility in children is still limited. The aim of this study is to review our experience with coupler-assisted venous anastomosis in young pediatric free flap reconstruction.

PATIENTS AND METHODS

This is a retrospective review of all children aged ≤10 years who underwent microsurgical free tissue transfer for traumatic or oncologic reasons from January 2016 to December 2018 in a tertiary care hospital. We used 10 years as an arbitrary cutoff age in the current study. The reason is the small body size of children less than 10 years compared to older children with larger body size and hence vessel sizes. All free flap reconstructions were performed using MACD for the venous anastomosis. The primary outcome of the current study was to determine flap

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survival rate at 30-day postoperative period. Secondary outcomes included venous thrombosis, flap take back, and flap salvage rates. Patients' demographics, American Society of Anesthesiologists physical status, and perioperative details were collected via hospital electronic records. Mean ± SD together with percentiles was used to summarize continuous and categorical variables, respectively. Approval was obtained from a local Institutional Review Board committee.

All vascular anastomoses were performed by the same surgeon. Arterial anastomoses were performed using conventional interrupted sutures. GEM Microvascular Anastomotic Coupler System (Synovis Micro Companies Alliance, Inc. Birmingham, AL) was used for the venous anastomosis. The operative technique of venous coupling system has been well described in the literature.[20] The size of the coupler was estimated by assessing the outer diameter of the vein using a vessel measuring gauge which is provided in the coupler kit. In case of minor discrepancy between the 2 veins (<3:1 ratio), the measurement of the smaller diameter was used to estimate the appropriate coupler size. Hand-sewn anastomosis was used if a significant size mismatch between the 2 veins (≥3:1 ratio) was encountered.

Heparinized saline at a concentration of 100 units/mL was used for intravascular irrigation. After completing flap anastomosis, all patients received intravenous heparin of 20 units/kg as an intravenous bolus before releasing vascular clamps. Postoperatively, all flaps were closely monitored in the pediatric intensive care unit for color, temperature, capillary refill, turgor, and Doppler signal. This continues hourly for the first 3 days, then tapered down over the course of 7 days. For osseous flaps, routine bone scan was done at the fifth postoperative day to assess the viability of the flap.

RESULTS

A total of 6 cases of free flap reconstruction in 5 young children were performed between June 2016 and June 2018. Four girls and 1 boy with a mean age of 7.3 ± 2.7 years (range 4–10 years) underwent 6 free flap transfers for head and neck, upper limb, and lower limb reconstructions. Three patients had an American Society of Anesthesiologists physical status of 3; the other 2 were either healthy or only had a controlled medical condition. Patients' demographics, flap type, and outcomes are summarized in Table 1.

Flap survival rate was 100% at 30 days postoperatively. There was no venous thrombosis, venous congestion, or partial flap necrosis. There were no other complications such as hematoma, seroma, or infection. Total time of intraoperative tissue ischemia ranged from 55 to 170 minutes with an average of 93 ± 40.9 minutes. Five out of 6 patients received postoperative prophylactic intravenous unfractionated heparin at a rate of 6–15 units/kg/h for 7 days. One patient developed intraoperative arterial thrombosis at the anastomotic site for which open thrombectomy was performed. The patient then received intra- and postoperative therapeutic heparin infusion at a rate of 26–29 units/kg/h. Two patients developed wound dehiscence 16 and 11 days following radial forearm fasciocutaneous free flap and free fibular osseous flap, respectively. Both patients failed conservative management and underwent successful surgical intervention with flap readvancement in the first case, and intraoperative debridement and primary wound approximation in the latter. In osseous flaps, postoperative bone scans at the fifth postoperative day confirmed the viability of all flaps and bony union was confirmed by serial follow-up imaging.

In total, 9 venous anastomoses were performed, one of which was done using simple interrupted sutures due to significant size mismatch between the recipient vein (external jugular vein) and the flap vein (radial vena comitans). The remaining venous anastomoses (8 out of 9) were performed using venous couplers, in the following types of flaps: 2 radial forearm fasciocutaneous free flap, 1 free latissimus dorsi flap, and 2 free fibular osseous flaps. All 8 venous anastomoses were performed in end-to-end fashion using 1.5–2.5-mm coupler devices. The coupler characteristics and recipient veins for each flap are described in Table 2. None of the flaps required revision of anastomosis or conversion to sutured anastomosis. All flaps had 100% venous patency rate. The mean coupling time was 7.1 ± 2.5 minutes. At a mean follow-up of 14.4 ± 8.2 months, all flaps were viable with no coupler-related complications. Two case examples are shown in Figures 1–3.

DISCUSSION

The use of MACD in venous anastomosis is well established in the literature. The current study confirmed its safety in young pediatric patients (younger than 10 years of age) with sizes ranging from 1.5 to 2.5 mm. In 1 case, 1 of 2 venous anastomoses was hand sewn due to significant vessel size mismatch (radial vena comitante to external jugular vein). Furthermore, venous anastomosis was performed at a mean time of 7.1 ± 2.5 minutes and hence shortening flap ischemia time and reducing operative times especially when performing 2 venous anastomoses for the flap. Coupler-assisted microvascular anastomosis has revolutionized the art of microsurgery and gained wide popularity due to many advantages: providing direct intima–intima contact and proper suture line eversion with no foreign material crossing the intimal wall (i.e., sutures).[21] In addition, the coupler external rings provide mechanical support which helps maintaining vascular patency.

Despite the common use of venous couplers, most of published literature was based on adult patients with reported patency rates comparable to sutured anastomosis. Whether these findings hold true in young children has yet to be thoroughly investigated. Few studies have addressed flap success and venous patency rates using venous couplers exclusively in pediatric free tissue transfers (Table 3). Starnes-Roubaud et al reviewed a total of 102 patients with a mean age of 12 years who underwent 109 free flaps, with 55% of the venous anastomoses performed using venous couplers.[22] The authors showed that

Table 1. Patients' Demographics, Flap Types, and Surgical Outcomes

No.	Gender	Age at Time of Surgery	ASA Classification	Comorbidities	Indication	Reconstruction Site	Flap Type	Preoperative Treatment	Total Time of Tissue Ischemia (min)	Complications	Follow-up (mo)
1	F	4	2	None	Gunshot injury to the face	Upper lip, lower lip, nasal lining, and right cheek defect	RFFF	None	75	Partial wound dehiscence managed with flap readvancement	25
2		5	2			Maxillary, alveolar and left cheek defect	Free fibular osteocutaneous flap	None	100	None	10
3	F	6	3	Left pelviureteric junction obstruction with grade 5 hydronephrosis	Extruded knee prosthesis post distal femur sarcoma reconstruction	Right knee defect	Free latissimus dorsi muscle flap	Chemotherapy	68	None	11
4	F	9	3	None	Post-Ewing sarcoma resection	Right femur defect	Free fibular osseous flap	Chemotherapy	90	None	17
5	M	10	1E	None	Electrical burn	Left hand revascularization and soft tissue coverage	RFFF flow-through	None	55	None	21
6	F	10	3	Tumor metastases to the lung	Postosteosarcoma resection	Left femur defect	Free fibular osseous flap	Chemotherapy	170	- SFA thrombosis, managed by open thrombectomy. -Wound dehiscence managed with intraoperative debridement and primary closure of the wound	2.5

ASA, American Society of Anesthesiologists; RFFF, radial forearm fasciocutaneous free flap; SFA, superficial femoral artery.

Table 2. Venous Couplers Characteristics

Coupling Time (min)	Coupler Size (mm)	Recipient Veins	No. Coupler Anastomosis	Flap Type
6	2.5	Facial, external jugular vein (sutured)	1	RFFF
3	2	Facial vein	1	Free fibular osteocutaneous flap
7	1.5	Anterior tibial vein	1	Free latissimus dorsi flap
9, 9	2	Venae comitantes	2	Free fibular osseous flap
6	2	Cephalic vein	1	RFFF flow-through
5.5, 11	1.5	Tributaries of the femoral vein	2	Free fibular osseous flap

RFFF, radial forearm fasciocutaneous free flap.

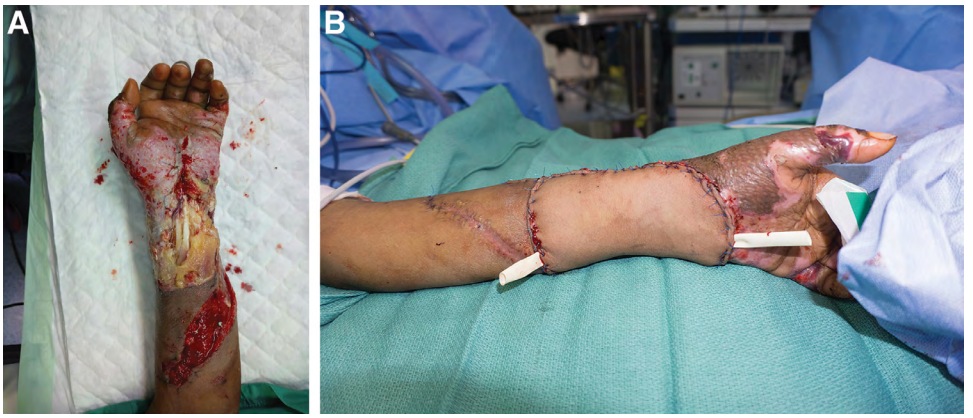

Fig. 1. Ten-year-old boy with electrical burn to left forearm, with exposed flexor tendons and median nerve, thrombosed ulnar artery, and radial artery. A, Preoperative view of left upper limb wound post electrical burn with extensive soft tissue defect in the volar forearm. B, Postoperative view of the defect reconstructed with radial forearm flow-through free flap.

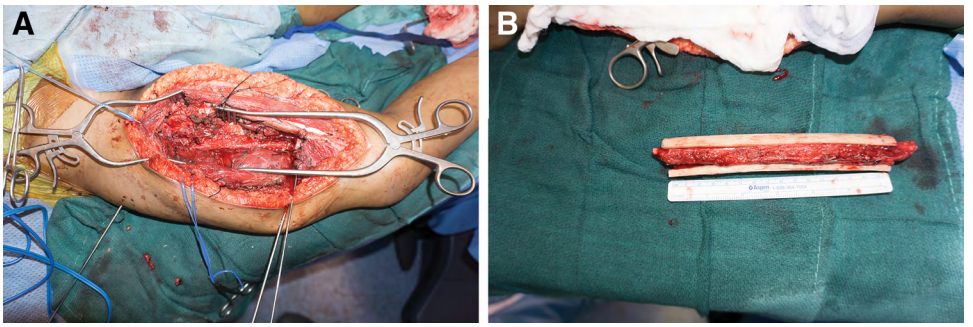

Fig. 2. Nine-year-old girl diagnosed with Ewing sarcoma of right femur, who underwent resection and reconstruction with free fibula osseous flap. A, Intraoperative view of the right femur post resection of the diseased bone (Ewing sarcoma). B, Harvested free fibular osseous flap.

compared to interrupted or running sutures, the use of MACDs was not significantly associated with higher rate of immediate complications (P = 0.572) nor long-term complications (P = 0.869). In another study, Acar et al evaluated the outcomes of anterolateral thigh flap in 11 pediatric trauma patients with a mean age of 8.9 years, ranging from 3 to 15 years.[23] A 90.9% primary flap survival rate was observed. One out of 4 flaps anastomosed with venous coupler was complicated with venous thrombosis 24 hours postoperatively, which was salvaged with a vein graft. The patient also had partial flap necrosis on the lateral edge and was treated with a skin graft. Guo et al analyzed the outcomes of 18 free fibula flaps performed in 16 patients for mandibular reconstruction.[24] The patients' age ranged from 10 months to 21 years with a mean age of 12 years. They had 100% survival rate with only 2 minor complications unrelated to the vascular anastomosis, a hematoma at the donor site, and an intraoral dehiscence that healed with conservative management. Although the authors stated that venous coupler was used for veins with internal diameter larger than 2 mm, the number of coupler anastomoses and corresponding coupler size were not reported. In the current series, we had 100% flap survival rate. Given the small vasculature of pediatric patients, relatively smaller couplers (1.5–2.5 mm) were used. All flaps healed with no venous complications.

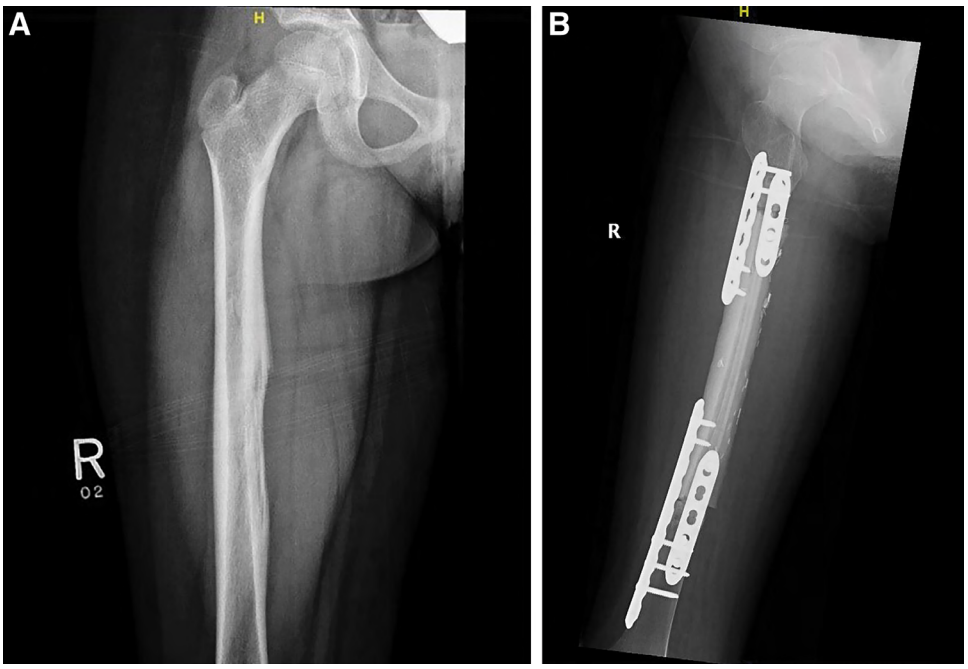

Fig. 3. Right femur Ewing sarcoma. A, Preoperative radiograph of the right femur shows an area of cortical disruption medially associated with multilayered periosteal reaction. B, Twenty-one-week postoperative radiograph shows an ongoing healing of the right proximal and distal femoral osteotomies with transfixed fibular osseous flap.

Table 3. Published Papers Addressing the Surgical Outcomes of Venous Coupler Anastomosis in Pediatric Patients

Study	Study Design	Reconstruction Site	No. Patients	Mean Age (Range) (y)	No. Free Flaps	No. Flaps Anastomosed Using Venous Coupler	Coupler Size Range (mm)	Venous Thrombosis Rate among Coupler-assisted Anastomoses	Overall Flap Survival Rate (%)
Acar et al[23]	Retrospective case series	Foot and ankle	11	8.9 (3–15)	11	4	2–2.5	25% Salvaged with a vein graft	100
Mountziaris et al[31]	Case report	Lower extremity	1	6	1	1	Not specified	0%	100
Starnes-Roubaud et al[17]	Retrospective comparative	Mixed	102	12.1 (3–17)	109	60	Not specified	Not specified	95.2
This study	Retrospective case series	Mixed	5	7.25 (4–10)	6	6	1.5–2.5	0%	100

A growing body of evidence exists on the use of venous couplers in adults. A recent systematic review of 13 studies with 2,976 coupler-assisted venous anastomoses has shown an average of 98.5% venous patency rate with overall thrombosis rate ranging from 0% to 3%.[4] Similar results were obtained in another systematic review of 25 studies which included 3,576 free flaps with 3,497 venous and 342 arterial coupled anastomoses.[25] Out of 3,497 coupled venous anastomoses, 61 venous thromboses were reported, equating to a 98.3% patency rate.[25] The size of coupler used for venous anastomosis was reported only in 59.8% of cases, which precluded accurate evaluation of anastomotic success rates in relation to different coupler sizes. MACDs were designed to be used in 0.8–4.3-mm-sized vessels, with available coupler diameter ranging from 1 to 4 mm with 0.5 intervals.[26] Some studies have shown that smaller coupler sizes tend to have lower success rates when compared to the larger ones. In a cohort of 437 free flap transfers in head and neck reconstruction in adults, each additional millimeter in coupler size was associated with a significant reduction of 41% in the revision rate.[27] In addition, timing of revision surgery varied among the coupler sizes: venous congestion requiring revision developed within 12 hours up to 4 days postoperatively in which ≤2.5-mm couplers were used, whereas no venous congestion developed after the first 12 postoperative hours in ≥3-mm couplers. This observation had practical implication in adjusting their flap monitoring protocol, putting great emphasis on frequent monitoring of longer duration for flaps with ≤2.5-mm couplers. Hanson et al reported a significantly higher rate of venous thrombosis (6.9%, $P = 0.04$) with the use of 1.5-mm couplers when compared to larger sizes.[28] In their study, the authors reviewed 5,643 free flaps with single venous outflow performed at a single institution. 57.7% of the cases were anastomosed using venous couplers. Compared with hand-sewn anastomoses, coupler anastomoses had a significantly higher thrombosis rate (1.2% versus 1.8%, respectively; $P = 0.02$). Interestingly,

when 1.5-mm couplers were excluded from the analysis, the difference in thrombosis rates between coupled and sutured anastomoses was not significant (1.6% versus 1.2%, respectively; $P = 0.53$). The authors recommended suturing venous anastomosis of less than 2 mm diameter when a larger alternative outflow is not available.

Coupler-assisted anastomosis is simpler, easier to learn, and faster to perform than hand-sewn anastomosis, reducing flap ischemic time as well as operative time.[4,25,29] In their systematic reviews, both Ardehali et al and Grewal et al reported a pooled mean of 5 minutes to complete the anastomosis, average time ranged from 3 to 11 minutes and 3 to 9 minutes, respectively.[4,25] Of note, not all included studies reported the mean coupling time. Head et al performed a practical cost-effect analysis of the use of microvascular anastomotic coupler system.[30] The authors demonstrated that the use of venous couplers will likely yield financial benefits specially when used in large-volume centers. A mean of 16.9-minute reduction in operating time was achieved with the use of 1 coupler device when compared with hand-sutured anastomosis, and an estimated reduction of operative costs by 519.29 US dollars was expected. Adding the savings of unused suture and subtracting the cost of disposable coupler rings lead to a total savings of $234.89 per use, recompensing the device's capital expenditure of $2,985 after 13 uses. Notably, these findings might vary from 1 center to another. Our data are in line with previous reports, demonstrating a mean coupling time of 7.1 ± 2.5 minutes. Estimating the operative time savings and subsequent cost benefits using venous couplers compared to sutured anastomosis was not possible in this series for the lack of a control group.

CONCLUSIONS

In the present study, venous couplers were shown to be safe and reliable in free tissue transfer in children younger than 10 years old. The aim of this study, although of its retrospective nature and small simple size, is to add to the limited literature on the use of anastomotic couplers in young pediatric microsurgery. Larger case series and comparative studies are still needed to advance our knowledge of surgical outcomes with venous couplers in young patients. The choice of the anastomotic technique relies greatly on intraoperative examination of the involved vessels making randomized clinical studies extremely difficult.

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