The Anatomic Features and Role of Superficial Inferior Epigastric Vein in Abdominal Flap

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Abstract

In lower abdominal flap representing transverse rectus abdominis musculocutaneous (TRAM) flap or deep inferior epigastric perforator (DIEP) flap, superficial inferior epigastric vein (SIEV) exists as superficial and independent venous system from deep system. The superficial venous drainage is dominant despite a dominant deep arterial supply in anterior abdominal wall. As TRAM or DIEP flaps began to be widely used for breast reconstruction, venous congestion issue has been arisen. Many clinical series in regard to venous congestion despite patent microvascular anastomosis site were reported. Venous congestion could be divided in two conditions by the area of venous congestion and each condition is from different anatomical causes. First, if venous congestion was shown in whole flap, it is due to the connection between SIEV and vena comitantes of DIEP. Second, if venous congestion is limited in above midline (Hartrampf zone II), it is due to problem in venous midline crossover. In this article, the authors reviewed the role of SIEV in lower abdominal flap based on the various anatomic and clinical studies. The contents are mainly categorized into four main issues; basic anatomy of SIEV, the two cause of venous congestion, connection between SIEV and vena comitantes of DIEP, and midline crossover of SIEV.

Keywords
- superficial inferior epigastric vein
- venous congestion
- deep inferior epigastric perforator flap
- transverse rectus abdominis musculocutaneous flap

Most flaps have arterial supply and venous drainage as form of pedicle artery and its vena comitantes. However, several flaps have independent venous drainage system from vena comitantes such as cephalic vein in radial forearm free flap. Another popular flap is lower abdominal flap representing transverse rectus abdominis musculocutaneous (TRAM) flap or deep inferior epigastric perforator (DIEP) flap.

In these flaps, the superficial inferior epigastric vein (SIEV) exists as superficial and independent venous system from deep system. The pedicle of TRAM and DIEP flap is deep inferior epigastric artery (DIEA) and its vena comitantes (VC-DIEA).

The whole process of blood flow in DIEP or TRAM flap can be summarized as follows. At first, arterial inflow proceeds from DIEA and reaches to subcutaneous tissue via perforator artery (or arteries). Through capillary circulation, blood flow returns to venous circulation. Before reaching to vena comitantes of DIEA (VC-DIEA), venous flow passes through SIEV. If

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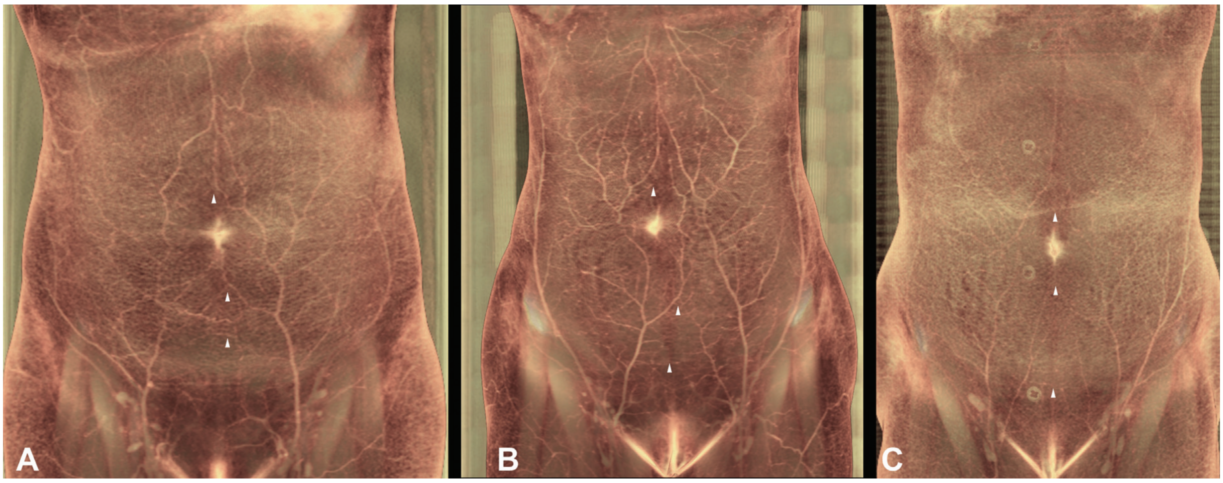

Fig. 1 General configuration of superficial inferior epigastric vein: (**A**) typical, symmetric configuration, (**B**) asymmetric configuration, and (**C**) large inverted V-shaped midline crossover arborized below inguinal ligament; arrow heads depict prominent midline crossovers.

the tissue above the midline is included in the flap, the venous flow of the contralateral side should pass through the midline during this process. Venous flow reaches to vena comitantes of perforator artery (or arteries) (VC-DIEP) via SIEV and finally outflow is drained through VC-DIEA.

TRAM and DIEP flap are commonly used for breast reconstruction and therefore, these flaps are harvested and insetted as large volume including tissue above the midline. Therefore, in the venous drainage process, midline crossover between the bilateral SIEVs have important role. Linking between SIEV and VC-DIEP acts like a gateway to deep vein (VC-DIEA). It also has key role in the venous drainage process.

In this article, the authors reviewed the role of SIEV in lower abdominal flap based on the various anatomic and clinical studies. The contents are mainly categorized into four main issues: basic anatomy of SIEV, the two cause of venous congestion, connection between SIEV and VC-DIEP, and midline crossover of SIEV.

Basic Anatomy of SIEV

The first anatomic study of SIEV was reported by Taylor and Daniel.[1] The importance of superficial venous network in epigastric area was described. The dominant superficial venous drainage despite a dominant deep arterial supply in anterior abdominal wall was also described in other cadaveric and in vivo studies.[2,3] In normal physiologic state, venous drainage passes predominantly through SIEV and partially contribution through VC-DIEA is occurred.[4]

SIEV has branches that drain into the thoracoepigastric vein superiolaterally and eventually drain into axillary vein via lateral thoracic vein. Inferiorly, SIEV crosses over the inguinal ligament and merges with deep system.[2] SIEV exists as individual vein from superficial inferior epigastric artery (SIEA) in most cases (99.3%). Rarely, it exists as vena comitantes of SIEA (VC-SIEA).[5]

SIEV locates medial from SIEA. In Kim et al's study, the average distance between the SIEA and SIEV was 17.64 ± 12.81 mm. SIEV is located superficially from Scarpa's fascia. VC-SIEA is located in the deep subcutaneous tissue compared with the SIEV.[6] Most of bilateral SIEVs shows symmetric configuration (87.3%). However, asymmetric configuration was also observed in 12.7% of computed tomography (CT) angiogram analysis (►**Fig. 1A, B**). Most midline crossover is originated above the inguinal ligament; however, in several cases (5.5%), large inverted V-shaped midline crossover was arborized below the inguinal ligament (►**Fig. 1C**).

Inferiorly, SIEV drains into the femoral vein in most cases (95.5%), except in rare cases drains into saphenous bulb.[7] Relation between SIEV, superficial circumflex iliac vein (SCIV), and VC-SIEA is categorized into four types. VC-SIEA drained into SCIV in 47.2% cases and SIEV in 20.8% cases. VC-SIEA drained into femoral vein directly in 9% cases, and VC-SIEA was absent in 22.9% cases.[5]

Two Anatomic Conditions in Venous Congestion and Venous Superdrainage of SIEV

One of the major problems in DIEP or TRAM flap is venous congestion despite patent microvascular anastomosis site.[8] Venous congestion has been reported to range from 2 to 20%.[9,10]

In 2001, Wechselberger et al have first reported the result of superdrainage of ipsilateral SIEV. They performed additional venous anastomosis to thoracodorsal, lateral thoracic, or intercostal vein and venous congestion was resolved successfully.[11]

Since then, many studies have been conducted on venous superdrainage and its beneficial effect.[12–14]

Venous congestion could be divided in two conditions by the area of venous congestion and each condition is from different anatomical causes. First, if venous congestion was shown in whole flap, it is due to the connection between SIEV and VC-DIEP is insufficient or absent. Second, if venous congestion is limited in above midline (Hartrampf zone II), it is due to problem in venous midline crossover.

Connection between SIEV and VC-DIEP

Venous connection between superficial system (SIEV) and deep system (VC-DIEA) is via VC-DIEP. Several anatomic studies were focused on this communication. Imanishi et al reported this communication in the paraumbilical region categorized into two patterns; direct communication between SIEV and VC-DIEP, polygonal venous network between SIEV and VC-DIEP. In latter pattern, large communicating vein exists between SIEV and VC-DIEA along with DIEP[15] (►**Fig. 2**). Schaverien et al observed no direct connection between SIEV and VC-DIEP in 8 out of 56 cases in magnetic resonance angiographic analysis. Venous congestion was shown in 7 cases (87.5%) among cases with no direct connection.[16] Recently, Taylor and colleagues also reported this communication and categorized it into two structures; One is venae communicantes which is direct communication between the main branches of the superficial and deep system. The other is venae comitantes widely separated from the SIEV and its main tributaries. Venae communicantes was located within 5 cm of the umbilicus over the rectus muscle.[17] Although the detailed nomenclature was different among studies, these anatomic series shows direct connection between SIEV and VC-DIEP is most important in venous drainage. For involving this direct connection, capturing paraumbilical perforators within 5 cm of the umbilicus during flap harvest is recommended.

Actually, Eom et al reported low DIEP of which upper border was 6 cm below the umbilicus showed significantly higher venous congestion rate than conventional DIEP flap (0% vs. 30.4%, $p = 0.007$).[18]

Midline Crossover of SIEV

The venous congestion limited in zone II and IV is another problem in DIEP or TRAM flap. In Blondeel et al's anatomic study of Microfil injection to right SIEV, large branches crossing the midline were found in only 18%. Indirect midline crossover was found in 45%, whereas 36% percent had no demonstrable midline crossing.[19] Schaverien et al's study showed fine vascular anatomy and serial venous flow in the flap. The venous flow crossing midline was via subdermal plexus. In this study, no midline crossover was seen in one flap and linking vein was seen only cephalad to umbilicus.[4] Rozen et al's report showed the venous anatomy of anterior abdominal wall more widely. There was three main location of midline crossover branches; immediately supraumbilical, immediately infraumbilical, and below the level of arcuate line.[3] Taylor and colleagues reported there were two important midline crossover—one is semicircular supraumbilical branch (between xyphoid process and umbilicus), the other is infraumbilical inverted V-shaped branch (between 2 and 4 cm below the umbilicus and near suprapubic crease). They recommended including at least one of these during the flap harvest.[17]

The authors analyzed dynamic venous flow of anterior abdominal wall using fresh cadavers and serial angiographic agent injection technique.[20] We could observe more detailed venous anatomy which could not be seen in previous studies. In this study, supraumbilical midline crossover is more favorable than infraumbilical midline crossover. This could be explained by the following reasons. Bilateral SIEV is shaped as inverted V-shape. The distance between the bilateral SIEVs is shorter in supraumbilical area and passing only one to two short polygonal venous networks is need for

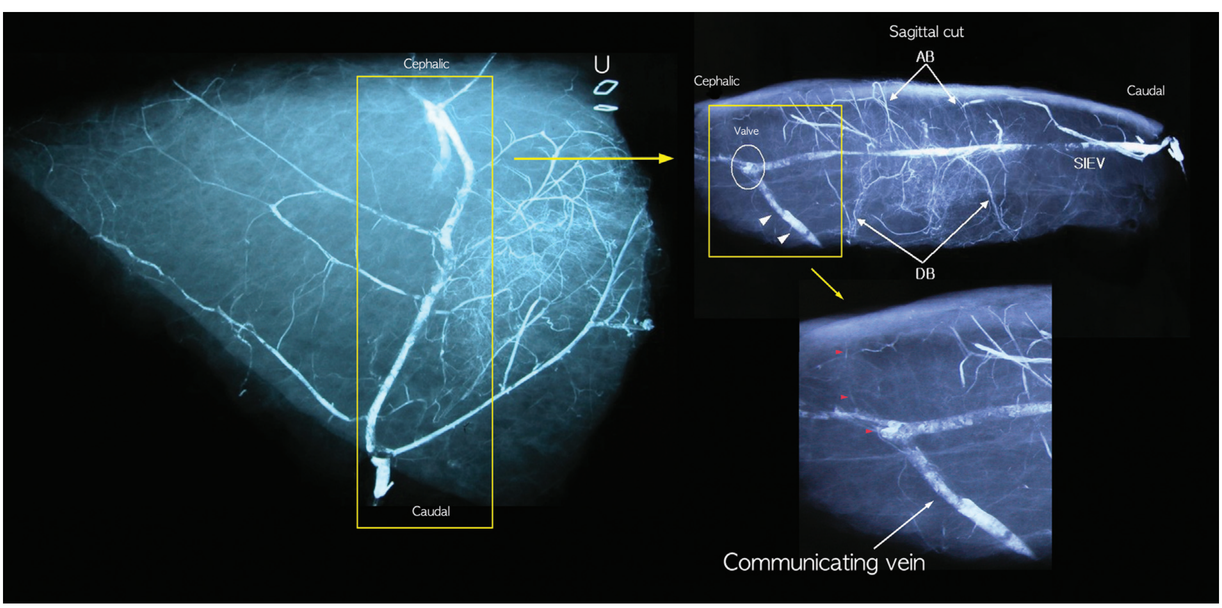

Fig. 2 Venogram in half transverse rectus musculocutaneous flap shows communication between superficial inferior epigastric vein and vena comitantes of deep inferior epigastric artery. Right picture shows sagittal-cut venogram of yellow rectangular area in left hemiabdomen specimen. Communicating vein is anastomosed with vena comitantes of deep inferior epigastric perforator (VC-DIEP) via polygonal venous network. Red arrow depicts VC-DIEP. AB, ascending branch; DB, descending branch; SIEV, superficial inferior epigastric vein; U, umbilicus.

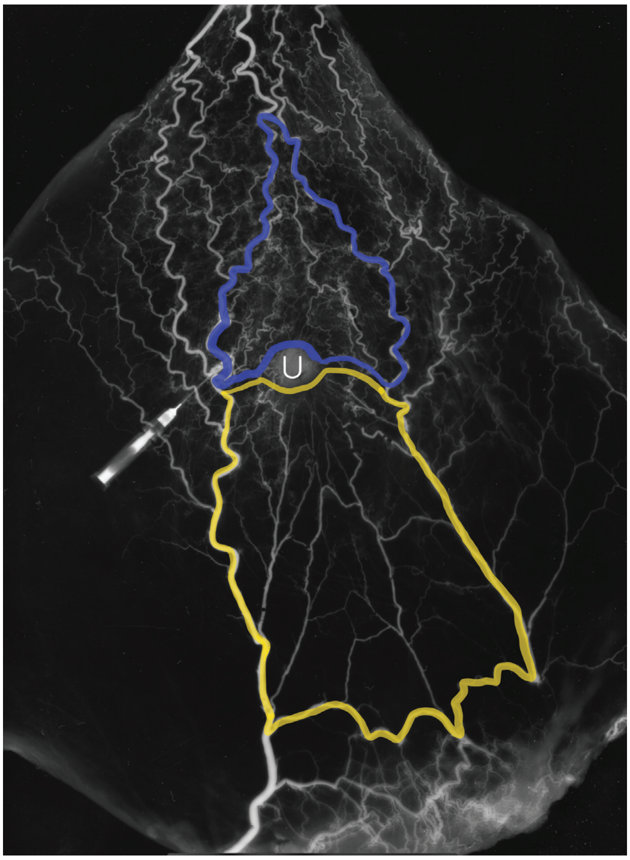

Fig. 3 Venogram shows difference of polygonal venous networks in supraumbilical area and in infraumbilical area. The distance between the bilateral superficial inferior epigastric veins is shorter in supraumbilical area and passing only one to two short polygonal venous networks is needed for midline crossing in supraumbilical area. U, umbilicus.

midline crossing in supraumbilical area. There are valves between midline branches and SIEVs and that interferes venous flow toward midline (►**Fig. 3**). Therefore, if supraumbilical midline crossover is included in the flap, it could be helpful to augment venous return in zone II or IV. However, it is difficult to include large supraumbilical midline crossover which was pointed out by Taylor and colleagues because the upper border of the flap becomes too high. Instead, a part of supraumbilical midline crossover could be possible because the mean distance from the umbilicus to evident supraumbilical midline was 18.39 ± 4.03 mm in CT angiogram analysis.[20]

If there is a need for a high inset rate including Hartrampf zone II or IV, additional superdrainage, or bipedicled flap could prevent perfusion-related complications. Especially, if estimated inset rate is above 0.75, these additional procedures are strongly recommended.[21] Based on our anatomic study, we recommend two surgical modifications during the flap harvest for better venous drainage above the midline without any additional procedures, especially in case of partial zone II is included in the insetted flap. First, if about one-third of zone II is included in the flap for insetting, preserving SIEV in zone II as possible is recommended. It is easy to encounter SIEV in zone II during the flap trimming and we could preserve the SIEV without injury. Because midline crossovers start from SIEV, this can be helpful to maximize venous drainage above the midline. Second, if above one-third of zone II is included in the flap, raising superior border of flap approximately 2.5 cm is helpful because it could capture partial supraumbilical midline crossover. Further clinical application is needed for validating this hypothesis from our anatomic study.

Discussion

The anatomic study of vein is more difficult than that of artery. Vein has valve which prevents regurgitant flow. Vein is thin and pliable. Therefore, it could burst out during the angiographic agent injection easily especially in small structures such as the venule and vena comitantes of perforator. In the angiographic study in limb venous anatomy, the interruption from valves can be overcome by anterograde perfusion using a tourniquet.[3] However, in abdomen, it is impossible to use a tourniquet. Therefore, Taylor and colleagues used hydrogen peroxide priming to render valves incompetent.[17] The authors prefer to use silicone rubber injection compound (Microfil) because its molecular size is small enough to pass through the capillaries[22] (►**Fig. 4**).

Recently, three-dimensional CT angiography (3DCTA) is widely used for various studies. Various images such as axial section, coronal section, and 3D-reconstructed image could be simply achieved with 3DCTA.[23] Stereoscopic radiographic image can be achieved using soft tissue X-ray system,

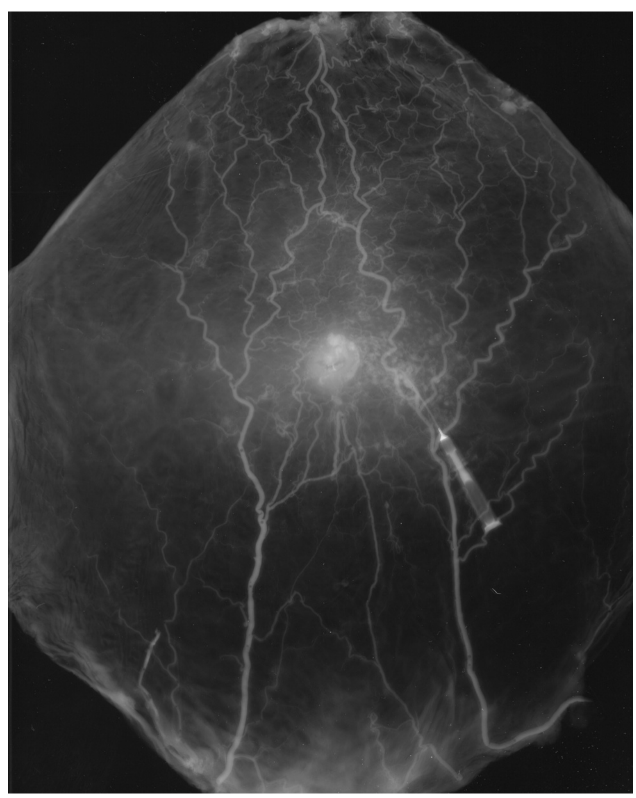

Fig. 4 Injection of Microfil via deep inferior epigastric perforator shows venous flow proceeding in superficial inferior epigastric vein (SIEV) which has passed through capillaries.

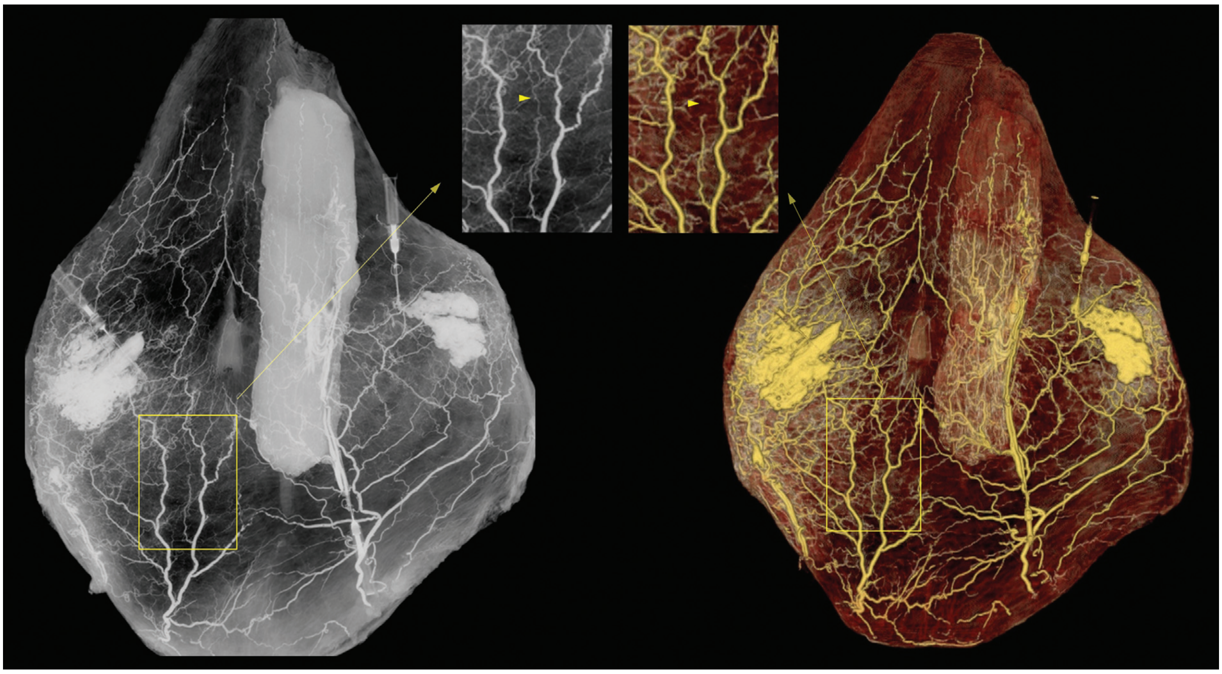

Fig. 5 Angiographic images acquired using soft tissue X-ray and three-dimensional computed tomographic angiography (3DCTA) from the same specimen. 3DCTA can simply show three-dimensional reconstructed image. Magnified image shows loss of fine vascular structure in 3DCTA which can be identified in soft tissue X-ray system (yellow arrow head).

however, it is difficult to analyze.[15] Nevertheless, there are several benefits of using soft tissue X-ray system. Once experienced, stereoscopic radiography gives 3D image with accurate direction. 3DCTA gives reconstructed 3D image in two-dimensional format. Therefore, accurate direction is relatively hard to achieve. In addition, 3DCTA could not visualize fine vascular structures especially if the size of vascular structure is smaller than the section thickness. This can be prominent during small animal experiments[24] (►**Fig. 5**).

Another difficulty in venous study is quantitative measurement of venous drainage. One study measured relative hemoglobin (rHb) concentration as an indicator of venous congestion using micro-lightguide spectrophotometer device.[25] In the study, rHb of zone IV and zone II were significantly decreased after supercharging of the contralateral SIEV. Several studies report evaluation of venous flow using indocyanine green angiography.[26,27] However, there are no standardized objective method which can evaluate the venous outflow in the flap.

In lower abdominal area, SIEA flap is also a useful flap. However, it is less popular due to short vascular pedicle and variable arterial anatomy.[28] In addition, SIEA flap is beyond the scope of this article because both arterial system and venous system are superficial system. Therefore, it was not covered in this article.

Conclusion

In lower abdominal flap represented by TRAM and DIEP, SIEV has key roles in venous drainage. Throughout the whole flaps, there is no flap that frequently uses tissues beyond the midline like as in lower abdominal flap, especially in breast reconstruction. Therefore, vascular problem and subsequent partial flap necrosis and fat necrosis have been an important issue. Understanding anatomic feature of SIEV will be helpful to reduce problems from venous compromise.

Author Contributions

Conception and design: S.O.P. and H.C. Acquisition of data: S.O.P., N.I., and H.C. Analysis and interpretation of data: S. O.P., N.I. and H.C. Writing or revision of the manuscript: S. O.P. and H.C. Final approval: all authors.

Ethical Approval

This study was approved by the Keio University School of Medicine Ethics Committee (approval no. 20070026).

Conflict of Interest

H.C. is an editorial board member of the journal but was not involved in the peer reviewer selection, evaluation, or decision process of this article. No other potential conflicts of interest relevant to this article were reported.

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