Constantine Mavroudis
Carl Lewis Backer *Editors*

Illustrations by
Rachid F. Idriss

Atlas of Pediatric Cardiac Surgery

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Preface

The raison d'etre for a new atlas of congenital heart surgery is based on the reality that our specialty has undergone numerous changes in the past few years, resulting in improved techniques and new operations. The sheer number of new procedures and the required attendant technical skills to successfully complete an operation have become a challenge to master, especially for residents who are pursuing a career in congenital heart surgery.

After three editions of our textbook, *Pediatric Cardiac Surgery*, and after numerous years of following and contributing to the literature, we concluded that there have been enough changes and enough advances to support an updated atlas of pediatric congenital heart surgery. The techniques espoused are mostly our own, but there is a great deal of similarity amongst international centers, owing to the influence of video presentations, manuscript publications, and chapter reviews. We therefore believe that the techniques illustrated in this atlas are likely to be similar to the techniques that are taught to residents and fellows throughout the world.

The atlas is organized generally by diseases and the procedures pertaining thereto. Many of the illustrations are from our textbook, *Pediatric Cardiac Surgery*, 4th Edition. Others are from our previous manuscripts, and still others have never been published before. Two general sections involve cannulation techniques and palliative procedures. A special section depicts difficult problems in the form of clinical vignettes that may arise during cardiopulmonary bypass, such as decreased venous return, undiagnosed patent ductus arteriosus, and technical errors leading to hemodynamic complications. This section will help the reader to become cognizant of the reparative measures needed to resolve these problems.

We have chosen procedures that cover the breadth of congenital heart surgery. This text perhaps is not totally inclusive, but we believe that the reader will find the greater majority of congenital heart procedures illustrated and explained.

An atlas of surgery is only as good as the medical illustrator. We are indeed privileged to be working with Rachid Idriss, MFA, who has immeasurable talents both in the execution of the detail and in the more difficult task of visualizing the anatomy in his own mind's eye. The details of depth, texture, and light are brilliantly shown to the observer. Except to explain the anatomy and different procedures from time to time, we have had little to offer him regarding how to organize the drawing or create his art. His ability to determine and emphasize the important steps of the operation seemed to be innate, a talent that Plato would find consistent with his theory of anamnesis, the idea that humans possess knowledge in the psyche that is rediscovered. The result is this very fine and well-illustrated atlas of pediatric congenital heart surgery.

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Acknowledgments

The editors would like to acknowledge the stellar editorial and organizational skills of Ms Allison Siegel whose indefatigable and conscientious efforts brought this book to fruition. This book was the culmination of 6 years of on again, off again labors that were interrupted any number of times for other so called more important tasks and responsibilities. Allison had the tenacity and vision to engage and reengage with this project, always keeping clear the eventual outcome that came together in the end as a worthy accomplishment.

Contents

Abbreviations

Ao	Aorta
AAo or Asc	Ascending aorta
ALCAPA	Anomalous left coronary artery from the pulmonary artery
AP	Aortopulmonary
APL	Transmural atrial pacemaker lead
ART	Atrial reentrant tachycardia
ASD	Atrial septal defect
A-V or AV	Atrioventricular
avn	Atrioventricular node
CA	Coronary artery
CPV	Common pulmonary vein or confluence of pulmonary veins
CS	Coronary sinus
Cx	Chest x-ray
Dao	Descending aorta
DV	Ductus venosus
FO	Foramen ovale
HV	Hepatic vein
INN A	Innominate artery
INN V	Innominate vein
IVC	Inferior vena cava
LA	Left atrium
LAA	Left atrial appendage
LAD	Left anterior descending coronary artery
LC or LCA	Left coronary artery or left carotid artery
LCC	Left coronary cusp
LCCA	Left common carotid artery
LCir	Left circumflex
LIV	Left innominate vein
LLPV	Left lower pulmonary vein
LPA	Left pulmonary artery
LSA	Left subclavian artery
LSVC	Left superior vena cava
LUPV	Left upper pulmonary vein
LV	Left ventricle
LVOT	Left ventricular outflow tract
MPA	Main pulmonary artery
MV	Mitral valve
NCC	Noncoronary cusp
NF	Nonfacing sinus
ORT	Orthodromic reentrant tachycardia
PA	Pulmonary artery
PDA	Patent ductus arteriosus

PFO	Patent foramen ovale or portal vein
PV	Pulmonary valve
RA	Right atrium or right arch
RAA	Right atrial appendage
RCC	Right coronary cusp
RC or RCA	Right coronary artery or right carotid artery
RCCA	Right common carotid artery
RLPV	Right lower pulmonary vein
RPA	Right pulmonary artery
RSA	Right subclavian artery
RSVC	Right superior vena cava
RUPV	Right upper pulmonary vein
RV	Right ventricle
RVOT	Right ventricle outflow tract
S-A or SA	Sinoatrial
SVC	Superior vena cava
TAPVR	Total anomalous pulmonary venous return
TV	Tricuspid valve
VSD	Ventricular septal defect
VV	Vertical vein
WPW	Wolff-Parkinson-White

Cannulation Techniques

1

Constantine Mavroudis

1.1 Aortic Cannulation

Aortic cannulation requires special care, especially in a neonate. In general, we use only one purse-string suture, employing a one-needle technique (Fig. 1.1) or a two-needle technique (Fig. 1.2). The site is just below the takeoff of the common brachiocephalic artery. The sutures are placed through the adventitia and into—but not through—the media. Transaortic sutures are avoided to prevent bleeding. If unwanted transaortic suture placement results in bleeding, the surgeon must assess its extent and magnitude. A transaortic suture often (but not always) must be removed and replaced to prevent ongoing bleeding during the procedure.

Once the suture is placed, a snugger tourniquet is applied (Fig. 1.3). The adventitia is dissected to the media within the confines of the purse-string suture line (Figs. 1.4 and 1.5) in preparation for aortic cannulation. With the left hand, vascular forceps firmly grip the aortic wall above (upstream to) the aortic purse-string. The surgeon retracts the forceps superiorly to expose the dissected cannulation site. A #11 blade is used to perform a small horizontal aortotomy within the confines of the dissected aorta inside the suture line (Fig. 1.6). As the blade is removed, downward traction is placed with the forceps to control the bleeding. In a coordinated movement, the forceps loosen the downward traction and expose the aortotomy (Fig. 1.7). Sometimes the aortotomy is too small, and the catheter may need to be manipulated. At other times, a small, curved mosquito clamp can be inserted to dilate the opening with or without opening the clamp. Once the cannula is placed (Fig. 1.8), the snugger is engaged and the cannula is secured with two ties, as shown in Figure 1.9. If bleeding persists from the purse-string suture line, a free silk tie can be placed around the base of the cannula while dragging the adventitia to the base (Fig. 1.10a–c). This maneuver generally controls the bleeding, as this tie can act as a second suture line.

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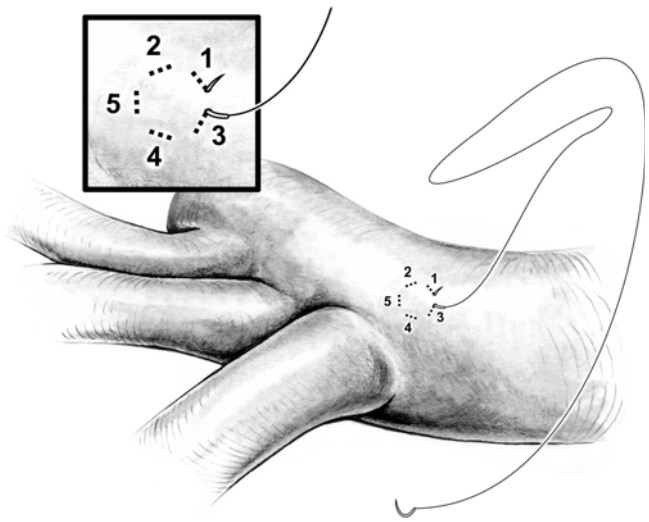
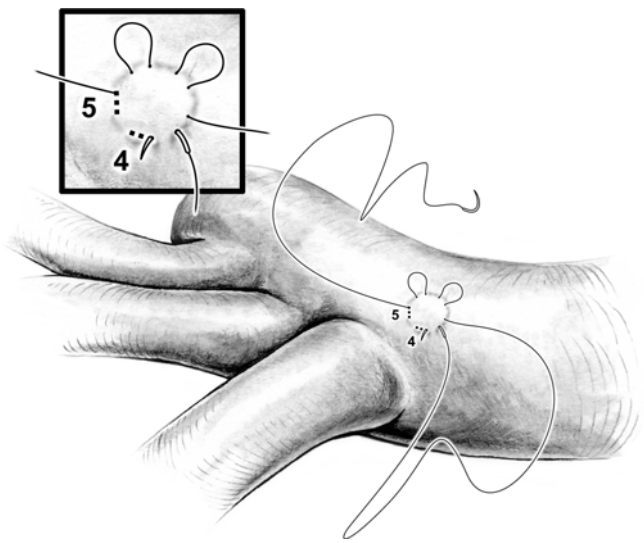


Fig. 1.1



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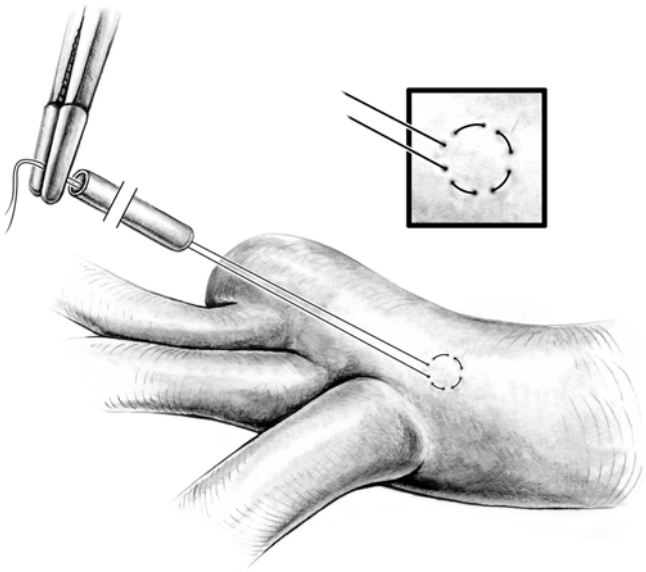


Fig. 1.3

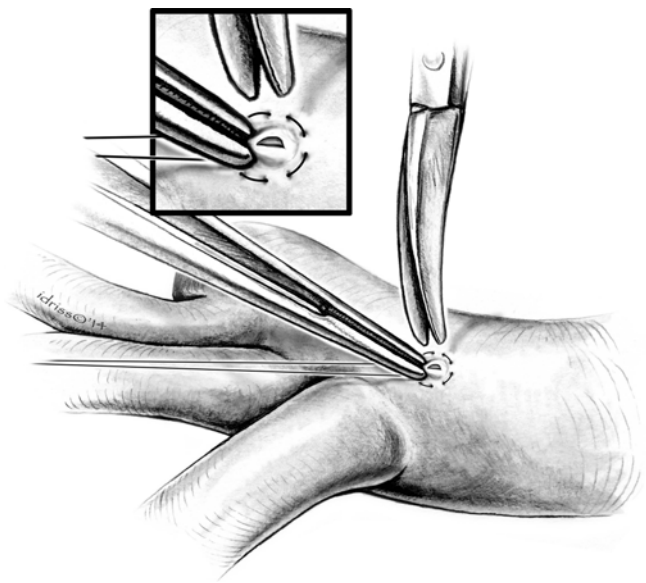


Fig. 1.4

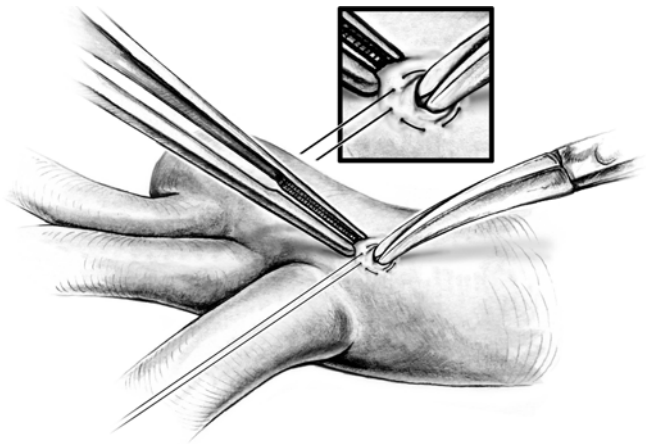


Fig. 1.5

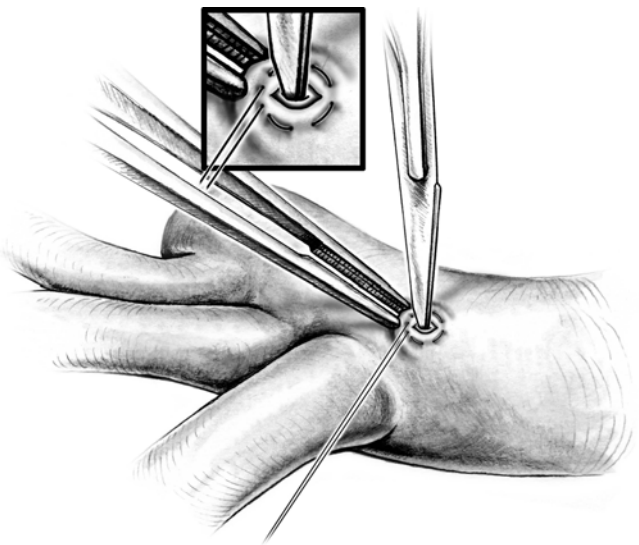


Fig. 1.6

Fig. 1.7

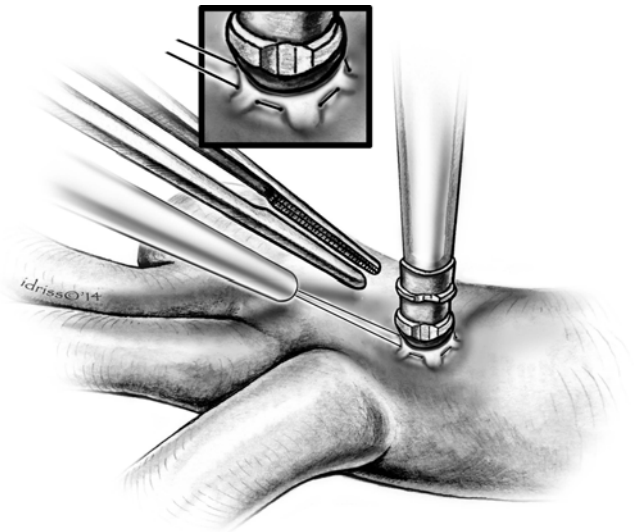


Fig. 1.8

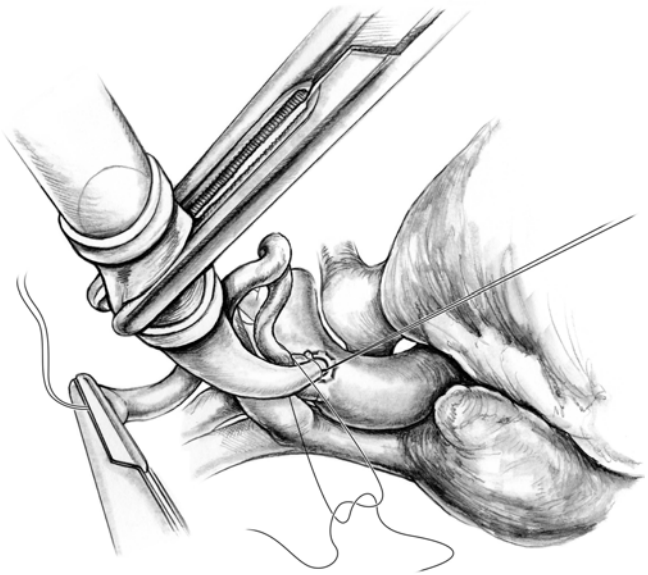


Fig. 1.9

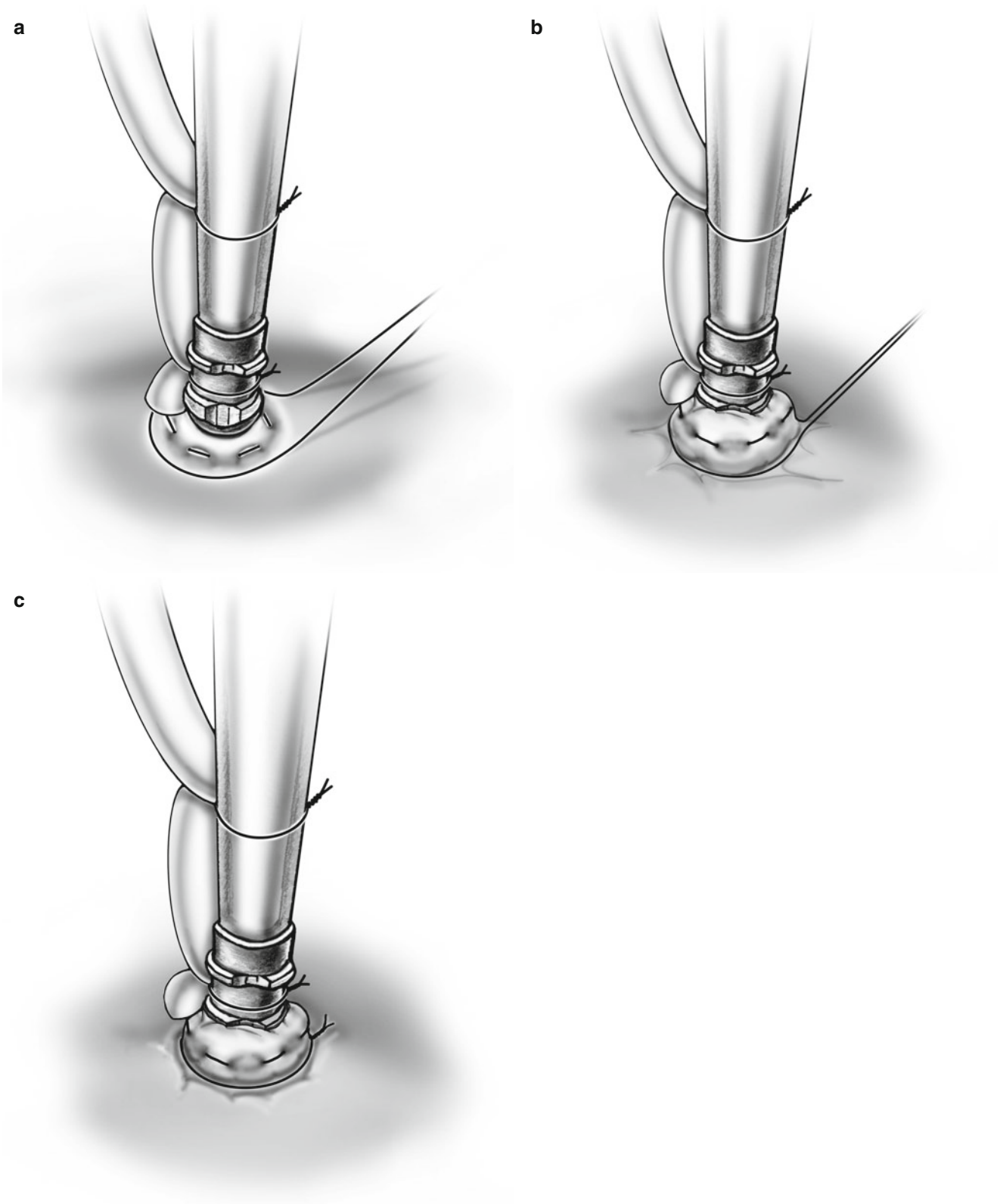
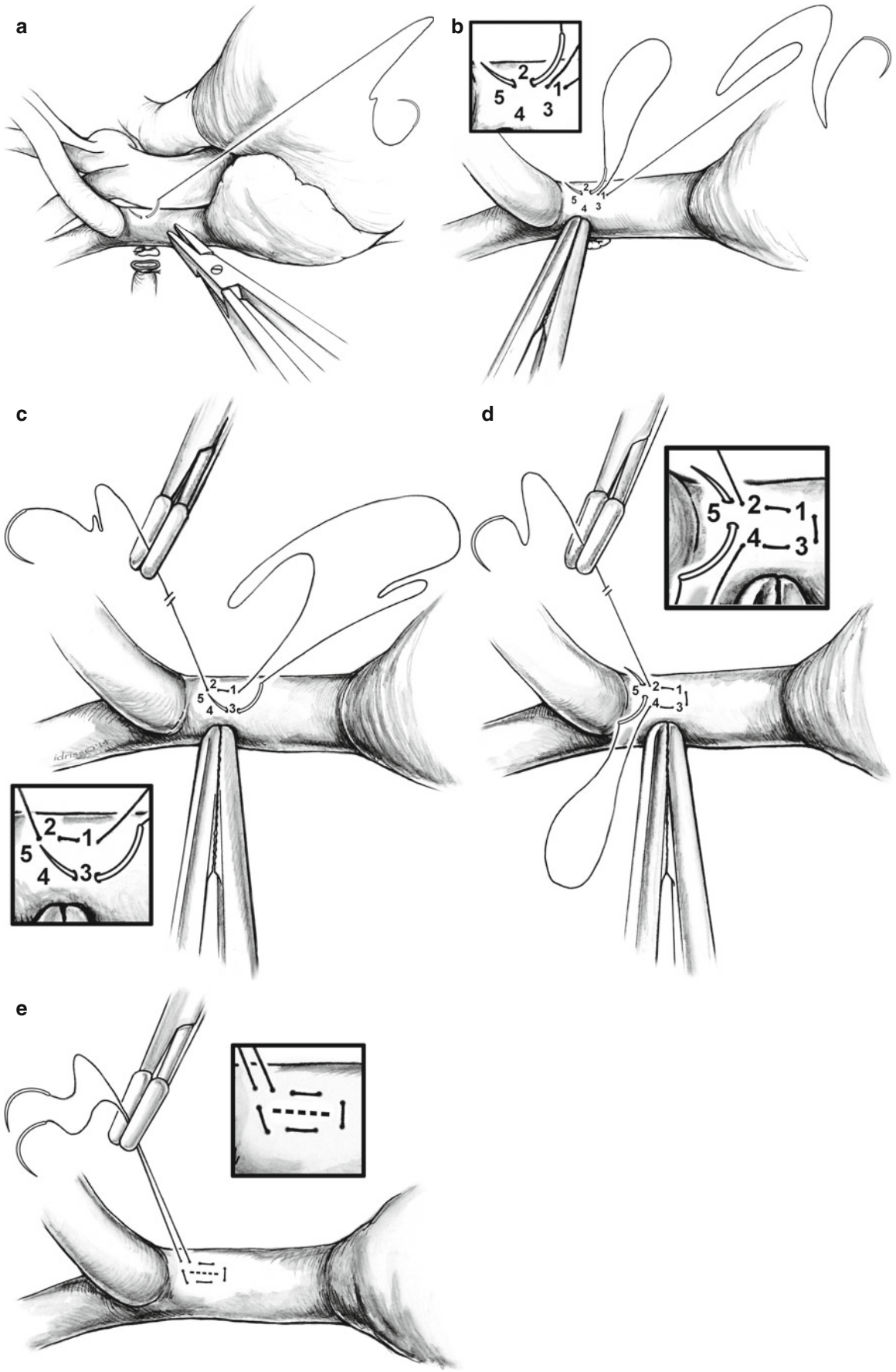


Fig. 1.10

1.2 Superior Vena Cava Cannulation

The superior vena cava (SVC) can be cannulated by a direct technique or by an indirect technique, which uses an atrial entry through the right atrial appendage or another atrial site. When direct SVC cannulation is indicated (e.g., partial anomalous pulmonary venous return, bidirectional Glenn shunt, or total cavopulmonary artery Fontan) a purse-string suture (Prolene; Ethicon; Somerville, NJ, USA) is placed in a rectangular fashion (Fig. 1.11a–e) just downstream to the entry of the brachiocephalic vein. (The numbers shown on the SVC in Figure 1.11b–d indicate the sequence of suture placement.) The azygous vein may or may not require ligation and division, depending on the anatomic and physiologic circumstances. The surgeon and assistant grip the medial and lateral SVC walls just outside the rectangular suture line and retract while the surgeon performs a venotomy (#11 blade) the length of the area within the purse-string (Fig. 1.12). The surgeons laterally retract the SVC, open the hole, and place the right-angled catheter into the opening (Fig. 1.13). The catheter is secured in place by engaging the snugger tourniquet while directing the tip of the catheter toward the brachiocephalic vein, as shown in Figure 1.14a. The untied ligature shown in this figure is a precaution in case bleeding complicates the cannulations. Figure 1.14b shows the cannula in place, with the SVC snugged for right atrial entry.

A transatrial appendage cannulation can be accomplished through an atrial appendage purse-string snugger (Fig. 1.15a, b). The assistant surgeon holds the forceps like a fork and compresses the atrial appendage while the surgeon amputates the appendage above the purse-string suture (Fig. 1.16). Both surgeons hold the opposing ends of the cut atrial appendage and retract laterally, thereby opening the hole while the surgeon inserts the catheter into the atrium, directing it to the SVC (Fig. 1.17). The catheter is advanced just above the entry of the azygous vein; guidance with the left hand is often required (Fig. 1.18a). The catheter is then secured by the snugger and a silk tie (Fig. 1.18b). When the surgeon desires single atrial cannulation, this transatrial appendage cannulation technique can be used to place the catheter in the atrium with the tip at the orifice of the inferior vena cava (IVC).



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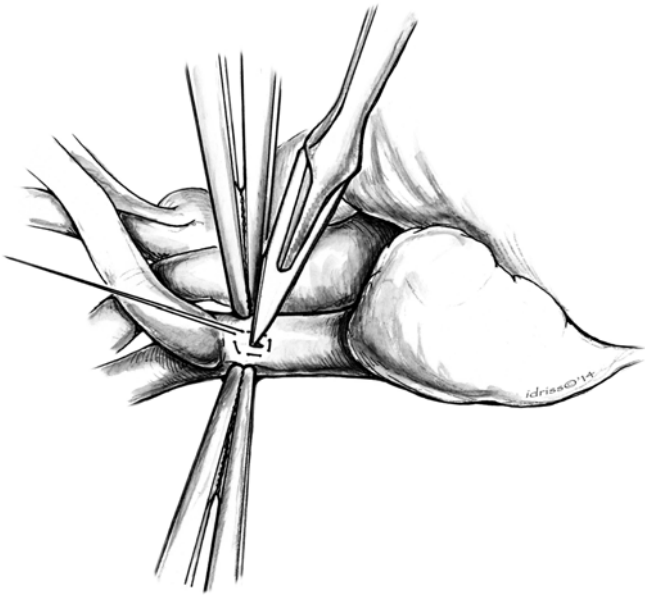

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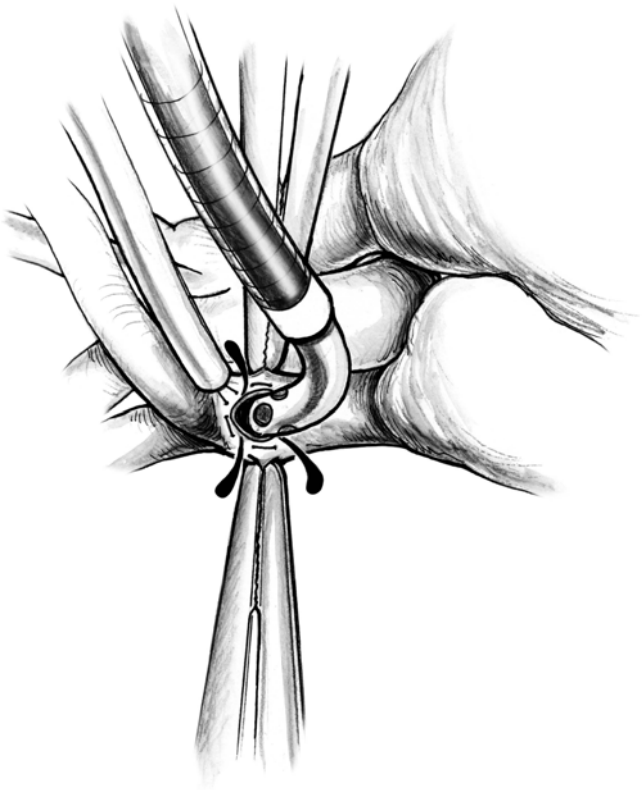

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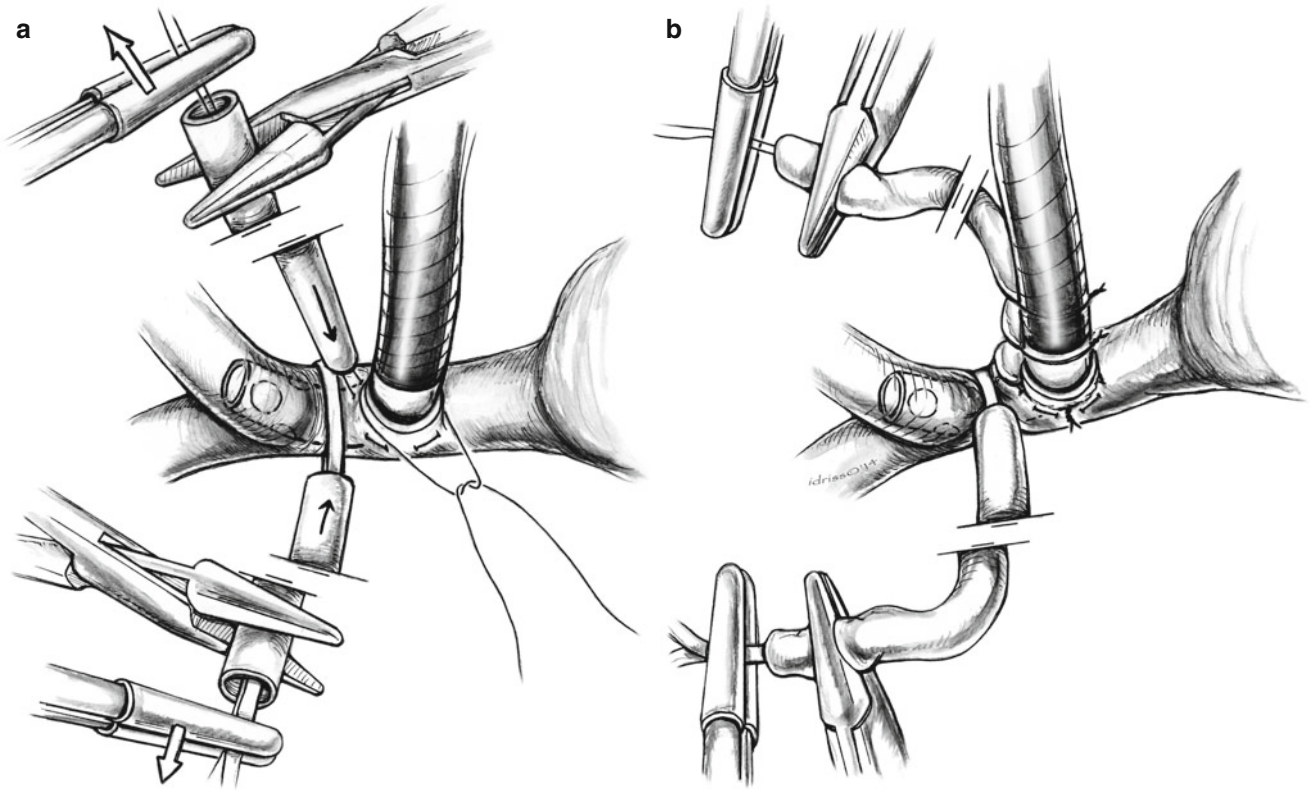

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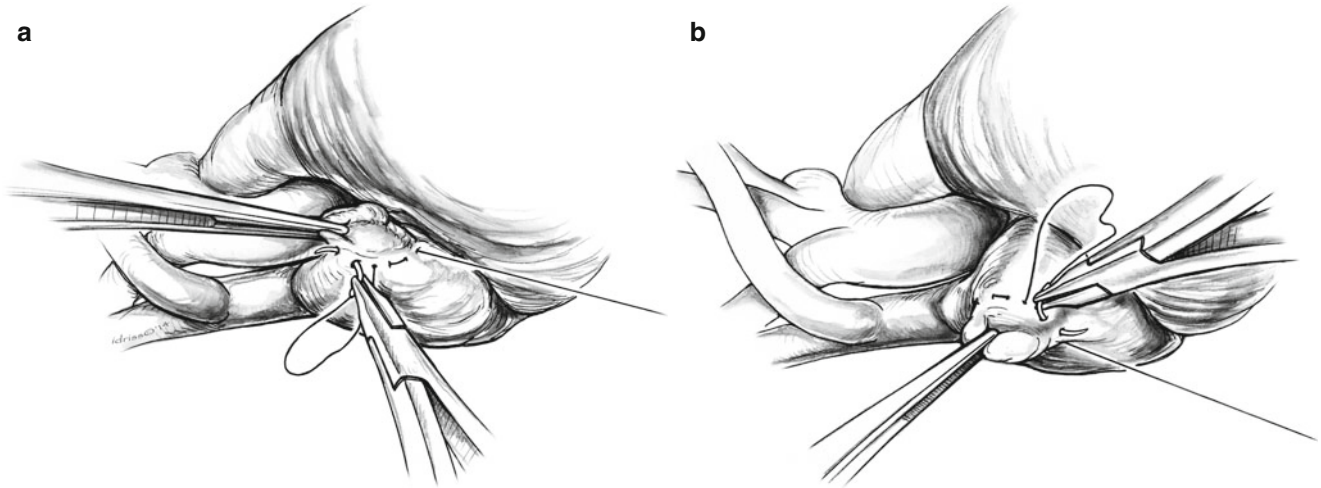

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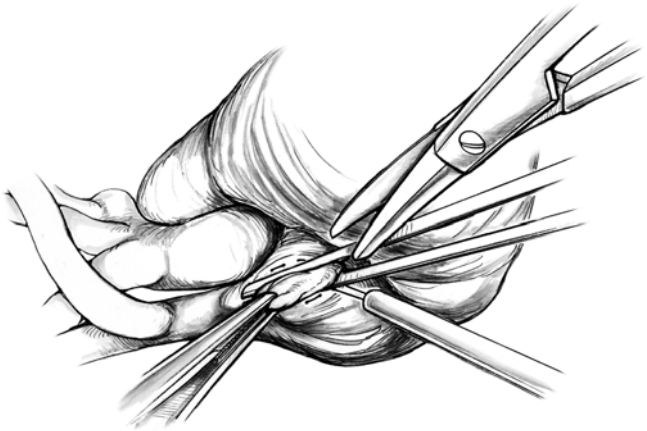

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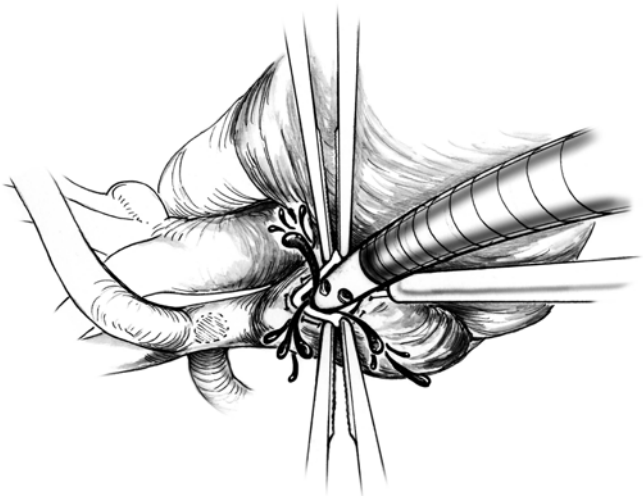

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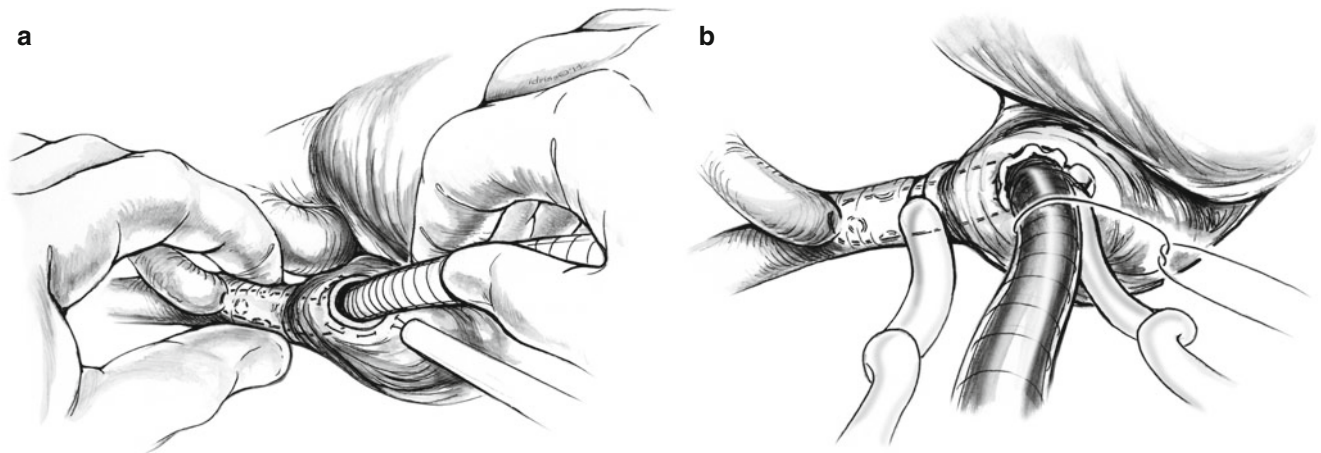


Fig. 1.18

1.3 Inferior Vena Cava Cannulation

The IVC can be cannulated at its entry into the right atrium (RA). A purse-string suture is placed at the IVC–RA junction or directly in the IVC, depending on the operation (Fig. 1.19a–d). The assistant surgeon uses forceps to retract the right atrium medially and superiorly with the right hand while the assistant and the surgeon control opposite sides of the suture line (Fig. 1.20). A pump sucker is placed medial to the IVC. A #11 blade is used to make an incision within the suture line, after which time the surgeon and the assistant surgeon close the hole by mutual medial direct pressure. The surgeon retracts laterally while a tonsil clamp is inserted into the hole for dilation (Fig. 1.21), followed by medial compression to control the bleeding. The processes are repeated, this time placing the catheter into the opening (Fig. 1.22) and controlling it by engaging the snugger and securing ties (Fig. 1.23).

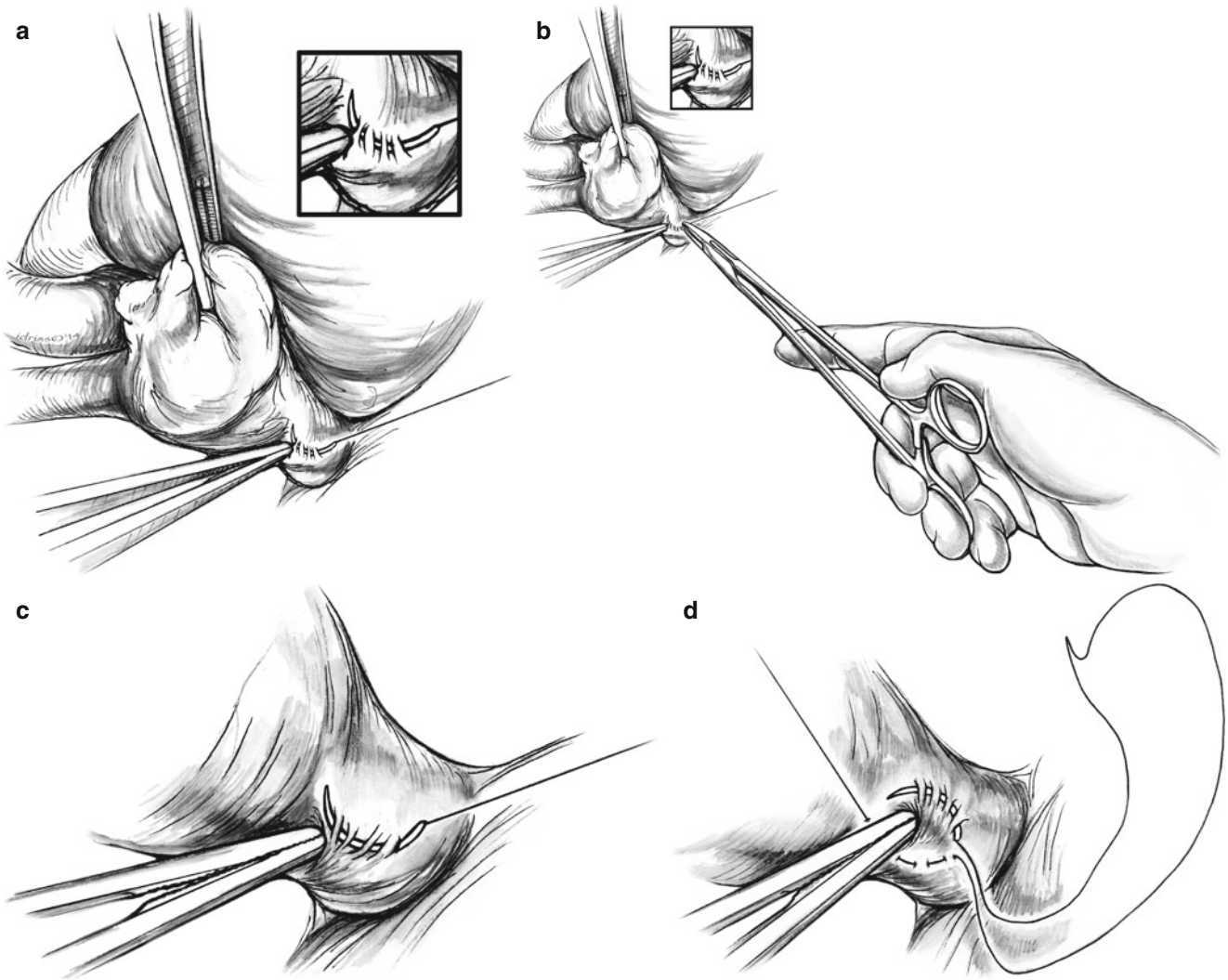
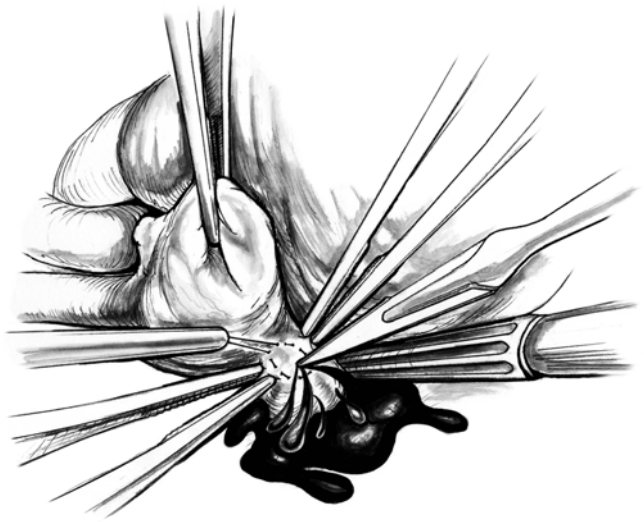


Fig. 1.19



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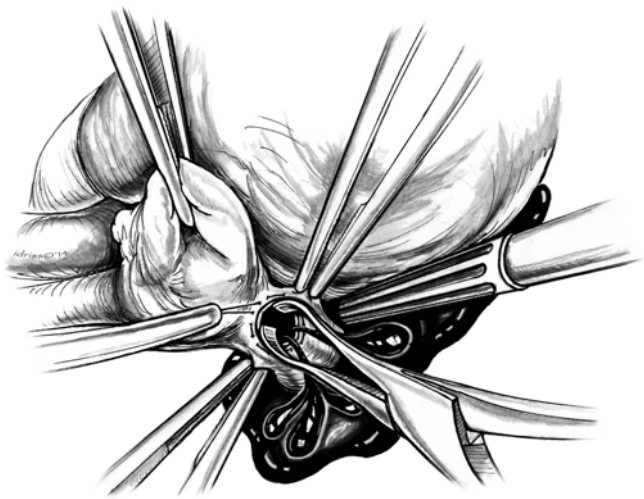

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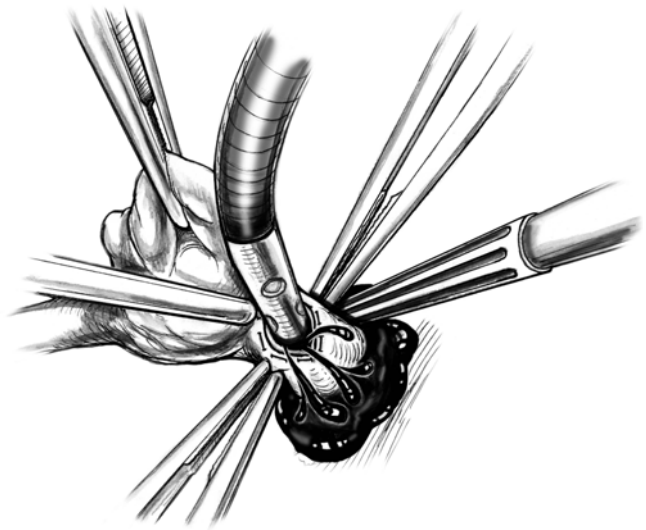


Fig. 1.22

Fig. 1.23

1.4 Femoral Cannulation

After the target (right or left) femoral cannulation site is selected and dissected (Fig. 1.24a), cannulation can proceed. It is important to clamp the common femoral artery (CFA) before the common femoral vein (CFV) to prevent outflow obstruction and extremity swelling. For the same reasons, post-bypass repair and release of the CFV should precede repair and release of the CFA.

The left CFA is clamped upstream and downstream of the target site, after which a transverse incision is made in the CFA for approximately 270° of the circumference (Fig. 1.24b). When the artery is small and the femoral cannula is relatively large, stay sutures are placed at the lateral edges of the arterial incision (Fig. 1.25) to help with the cannulation. The cannula is placed into the proximal CFA orifice while the proximal clamp is released (Fig. 1.26). The catheter is then gently advanced and secured. Sterile mineral oil, when available, is often used to coat the femoral cannula before insertion. The CFV is cannulated in a similar fashion (Fig. 1.27) except that the large cannula is advanced as high into the IVC as possible. Sometimes a guide wire or a small nasogastric tube is advanced first into the IVC and is followed by the large venous catheter (Fig. 1.28). Catheters are secured by clamps or sutures as necessary.

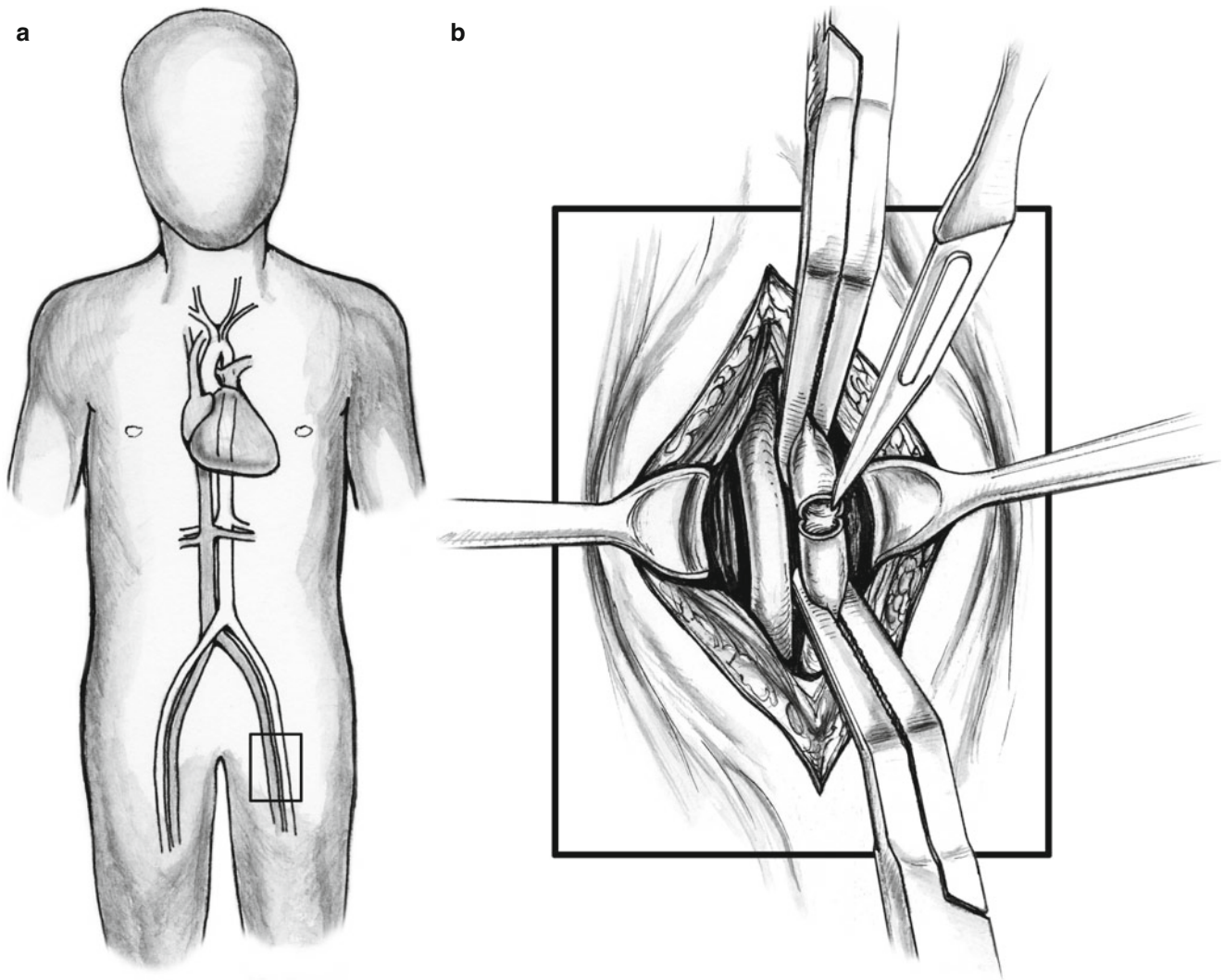


Fig. 1.24

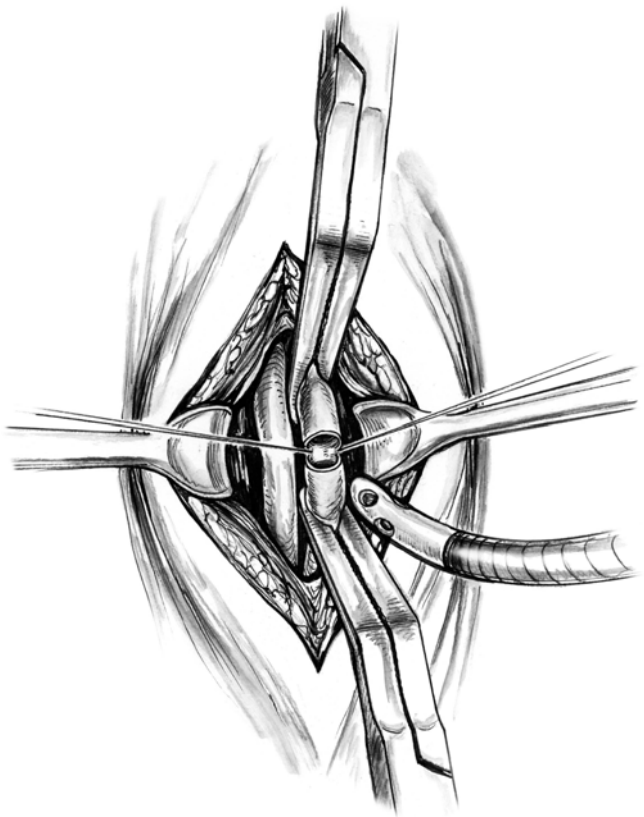
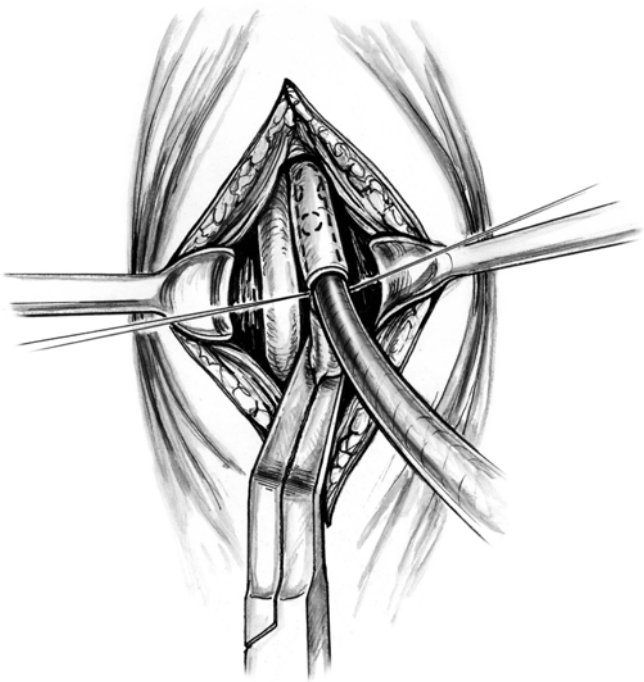


Fig. 1.25



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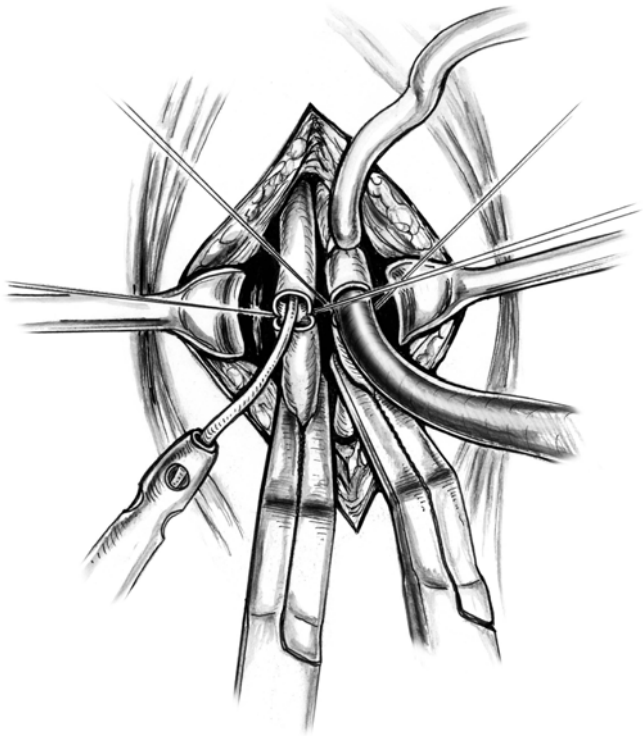

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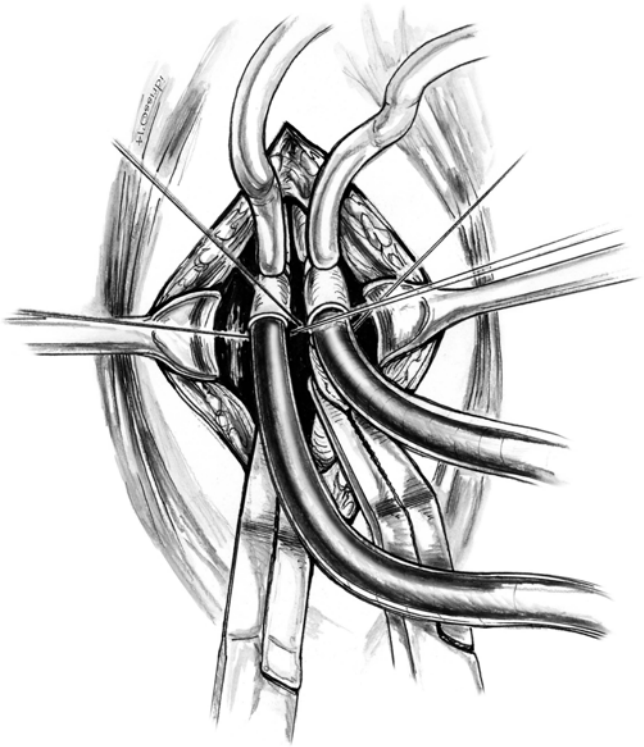

Fig. 1.28