5 Catheter Placement and Model Reconstruction

Yan Wang

Abbreviations

AP	Anterior posterior
LAO	Left anterior oblique
PA	Posterior anterior
PVA	Pulmonary vein antrum
RAO	Right anterior oblique
RVOT	Right ventricular outflow tract
SVT	Supraventricular tachycardia

Introduction

Electrophysiological study and catheter ablation procedures are traditionally performed using fluoroscopic guidance, which can be associated with considerable radiation exposure that is potentially harmful to the patients and the medical staffs. Protective lead apparel can only partially reduce harmful radiation to medical staffs and the patients are still left at risk of radiation exposure. It has been estimated that 1 h of radiation exposure is associated with a rise of 0.1% in the lifetime risk of developing a fatal malignancy [1].

In the past decade, more and more reports suggest that electrophysiological study and catheter ablation procedures can be performed without fluoroscopic guidance just using three-dimensional navigation system [2–11]. Here we introduce the tips and points about catheter placement and model reconstruction without fluoroscopic guidance.

Catheter Placement

Navigation Systems

Both three-dimensional navigation systems including electric-field mapping system (e.g., EnSite NavX™) and electric-magnetic mapping system (e.g., Carto™) can be used for zero-fluoroscopic electrophysiological study and ablation.

Relevant Preparation

1. Apparatus for pressure measurement
   (a) Extension tube with stopcock: A tube is routinely used for pump injection; the tube comprises a male Luer slip connector at one end and a female Luer slip connector at another end; the male connector is used for collecting a needle and the female collector is for collecting a stopcock or a syringe (Figs. 5.1 and 5.2).

Y. Wang (✉)
Cardiovascular Division, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China
e-mail: newswangyan@tjh.tjmu.edu.cn

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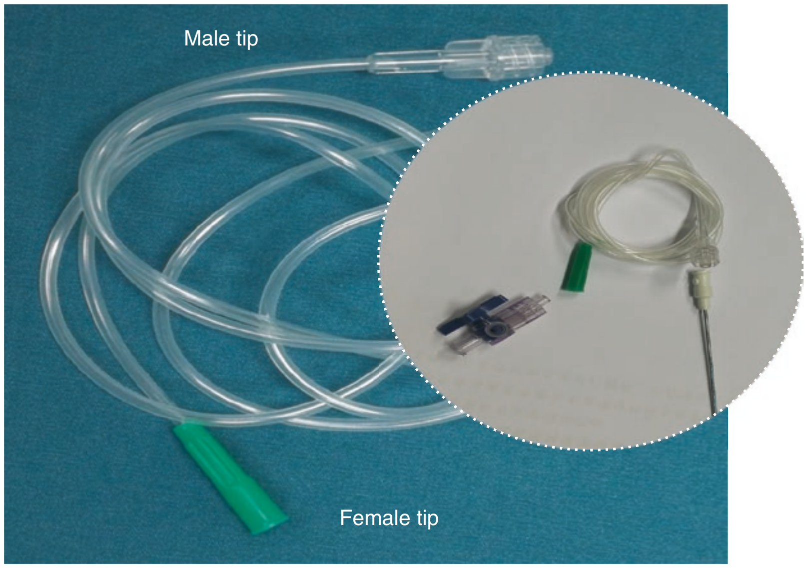

Fig. 5.1 An extension tube is utilized for pressure measurement or simplified blood return test. The male connector is used for collecting a needle; the female collector is used for collecting a stopcock or a syringe

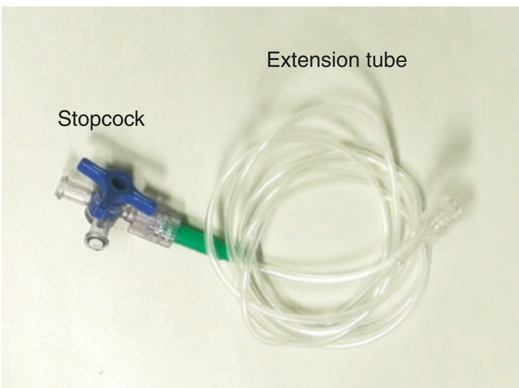

Fig. 5.2 The extension tube is collected with a stopcock and is filled with natural solution before puncture

(b) Portable manometer (optional): A manometer is used for pressure measurement by collecting the needle with an extension tube.
(c) Invasive blood pressure monitoring system and transducers (optional): A system is routinely used for manometer during coronary angiography.

2. Monopolar guide wire (optional): The tip of monopolar guide wire is conductive and it extends to a conductive metal tail through which a three-dimensional navigation system can be collected.
3. Clip-pin or clip-clip adaptor with cable (optional): The alligator style clip can be attached to the conductive tail of a monopolar guide wire and the pin can be inserted in the pin box of a three-dimensional navigation system. A clip-clip cable can be used for navigation if a clip-pin cable is not available. Thus, the operator needs to manually make a pin. Peel the plastic shroud of the pins of a cable designed for linking diagnostic electrophysiological catheter and collect the clip to the peeled pin and finally insert the "clip-peeled pin" assembly into the pin box (Fig. 5.3).

Confirmation of Venous Access

A real venous access is particularly important, especially when a subclavian vein or an internal jugular vein is punctured; mechanic compression is difficult to achieve hemostasis in those veins; a surgery might be required in case of bleeding.

Under fluoroscopic guidance, a real venous access can be confirmed by the following manifestations: (1) the characteristic color of venous blood and (2) the consistent venous rout of a J-shaped wire revealed by fluoroscopy.

Without fluoroscopic guidance, a venous access can be verified by the following tips:

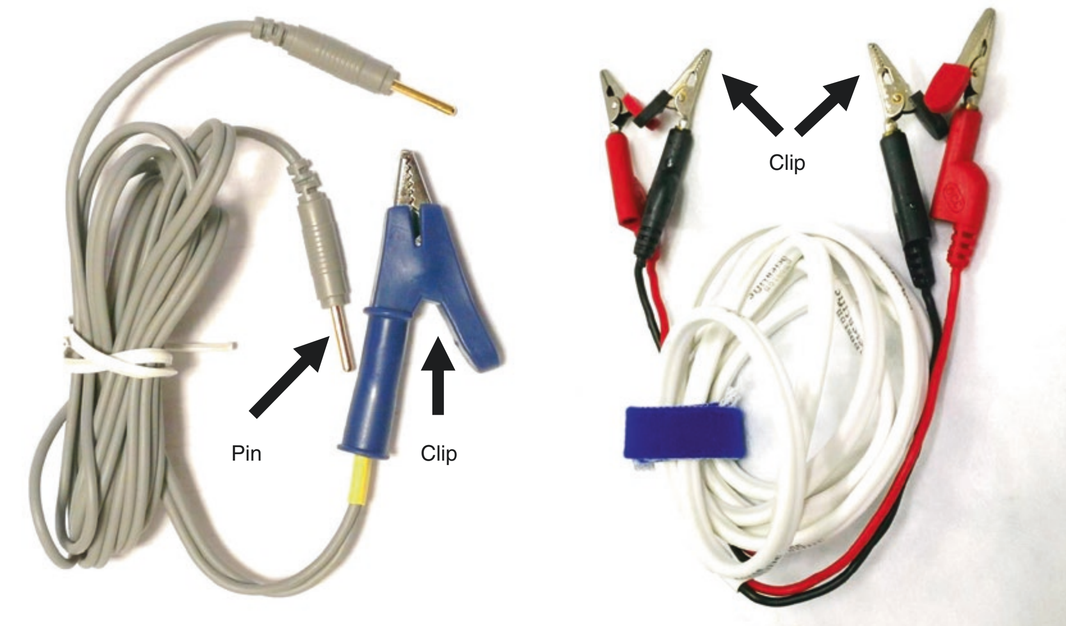

Fig. 5.3 A clip-pin adaptor with cable is utilized for three-dimensional navigation; the conductive tail of a monopolar guide wire is collected with the alligator-style clip and the pin is inserted into the pin box of the navigation system. A clip-clip cable can be used for navigation, and the operator needs to manually make a pin in this situation. Peel the plastic shroud of the pins of a cable designed for linking diagnostic electrophysiological catheter, collect the clip to the peeled pin, and finally insert the "clip-peeled pin" assembly into the pin box

Pressure Measurement

The pressure in the punctured vessel can be evaluated by the following methods:

1. Blood return test: A venous access can be confirmed if the blood flows back to the needle when you just lift the extension tube filled with natural solution (Figs. 5.4 and 5.5).
2. Portable manometer: A portable manometer can measure the pressure within the punctured lumen via an "extension tube" collected to the needle and help you to verify a venous access.
3. Transducer and invasive blood pressure monitoring system: The pressure can be measured using transducer and invasive blood pressure monitoring system via an "extension tube" collected to the needle.

Interference Test

The test is often used to confirm a correct venous access when a subclavian vein or an internal jugular vein is punctured for introducing a catheter with fixed curve into coronary sinus [2].

Using electroanatomic navigation system, this technique can be applied according to the following steps:

1. A catheter with fixed curve is advanced to the right atrium via femoral vein and then a rough model is constructed.
2. The tip of catheter is placed at the middle of right atrium via three-dimensional navigation system (e.g., EnSite NavX™).
3. A subclavian vein or an internal jugular vein is punctured, and then a J-shaped guide wire is inserted into the needle and collected to a three-dimensional navigation system via a clip-pin cable. The push-and-pull manipulation of guide wire may lead to passive movement of the catheter placed at right atrium; additionally, rotation of the catheter may touch the J-shaped wire and lead to interference signal seen in the screen (Fig. 5.6).

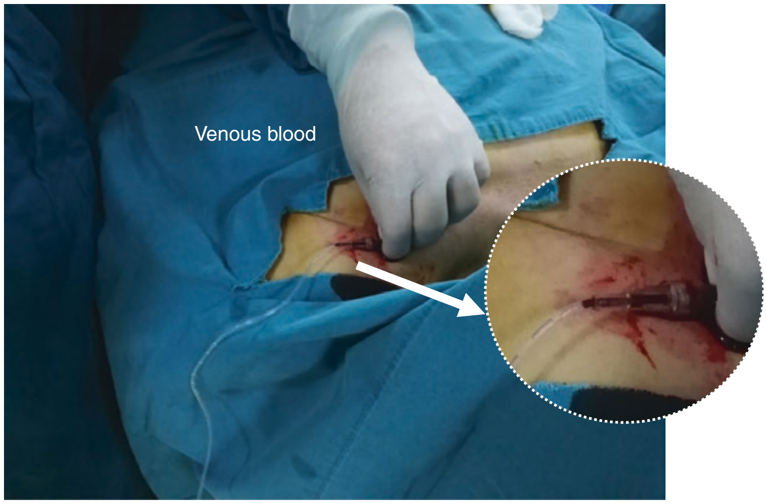

Fig. 5.4 Blood pressure was roughly estimated with an extension tube filled with natural solution and collected to the needle. Venous blood flowed out of the needle when the tube was dropped below the needle

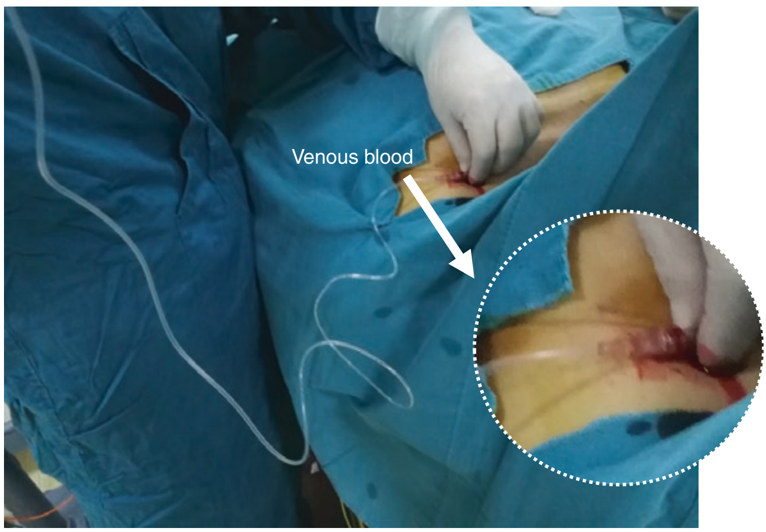

Fig. 5.5 Venous blood returned into the needle when the tube was raised above the needle

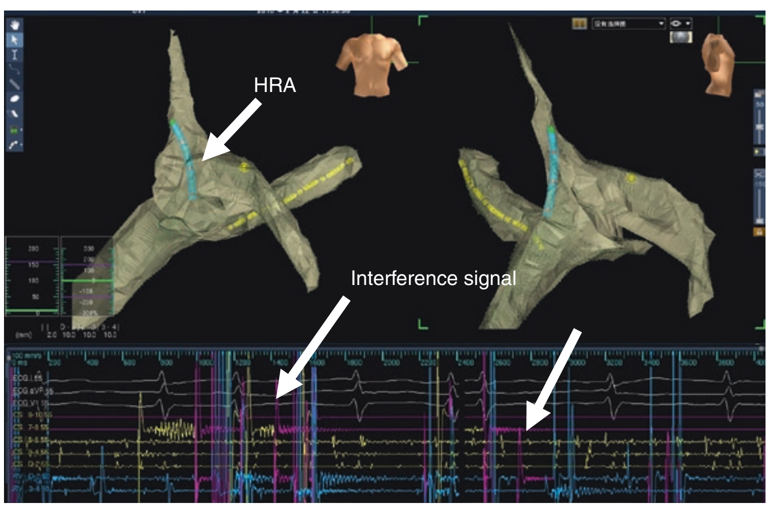

Fig. 5.6 Interference test is usually used for confirming the venous access of subclavian or internal jugular vein. The interference signal can be seen in the monitor by the entanglement of the catheter via a femoral vein with the J-shaped wire placed via subclavian or internal jugular vein

Monopolar Guide Wire

The tip of a special-designed monopolar guide wire can be exactly located by three-dimensional system. It can be inserted into the needle after a puncture and the metal conductive tail can be collected to a three-dimensional system using a clap-pin adaptor with cable.

Tips for Catheter Manipulation

Without fluoroscopic guidance, catheters can be efficiently placed according to the following tips:

1. Prefer a catheter with a soft tip except there is a special need.
2. A femoral vein access as well as a steerable catheter are preferred for coronary sinus catheterization, which will save the time for confirming a venous access and reduce the potential risk of pneumothorax or hemothorax.
3. The introducing sheath should be large enough to allow advancing or withdrawing catheters smoothly; the skin and local tissue should be cut and dilated appropriately if a long sheath is used for introducing catheters.
4. Important anatomic positions should be labeled and the length of the catheter should be roughly estimated before catheter placement; generally we place the tip of a catheter at about three fingers cranial to the xiphoid process, and observe the distance between the collector or handle of a catheter and the patient's heel (Figs. 5.7 and 5.8).
5. In order to reduce the friction force and improve the sense of resistance from the tip of catheters, all catheters should be bedewed with heparinized natural water immediately before and during catheter manipulation.
6. All the manipulations must be gentle; this is the case especially with zero-fluoroscopic technique. "Short-distance advancement and slightly hold" technique, instead of "large-distance advancement and tightly clench" technique, is preferred for catheter manipulation; insert 1–2 cm each time by more

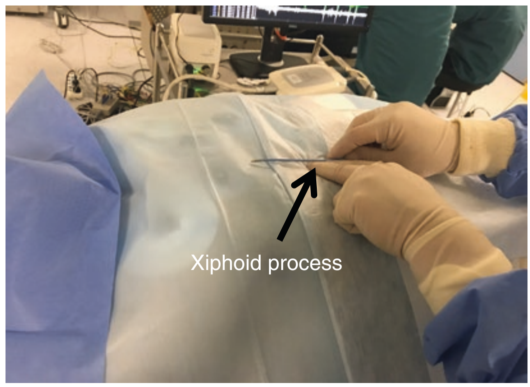

Fig. 5.7 The operator placed the tip of an ablation catheter three fingers cranial to the xiphoid process and marked with a blue dot on the monitor of the Carto system

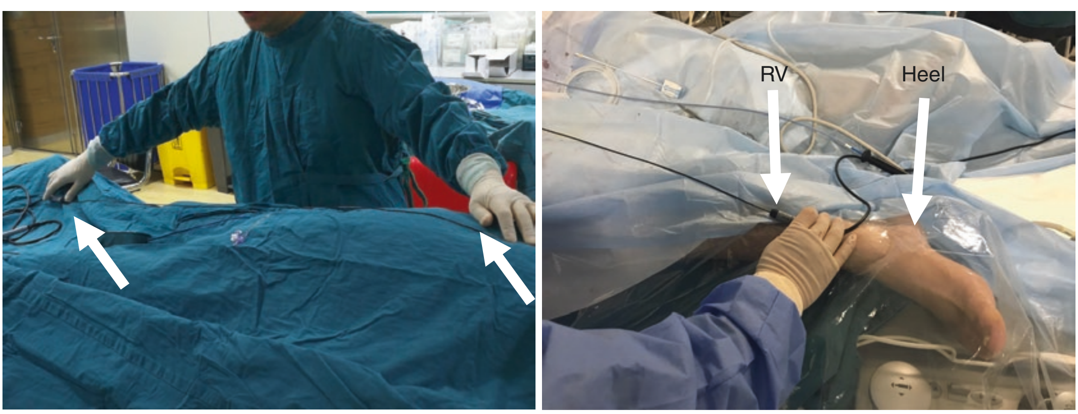

Fig. 5.8 The operator placed the tip of a right ventricular (RV) catheter near the xiphoid process and observed the distance between the catheter's tail and the patient's heel

times and hold the catheter with the slightest force using the thumb and index finger for catheter insertion, whereas 3–5 cm each time, less times, and tight clench with all the fingers are not recommended (Figs. 5.9 and 5.10).

7. Choose proper views for inserting catheters into particular structure; anterior-posterior (AP) view plus right lateral (RL) view is recommended for catheter insertion through venae cava since almost big venous bifurcations extend laterally. The two views are also recommended to place a catheter into a superior vena cava; as a RAA is located at the anterior and lateral part of a right atrium, the operator manipulates the catheter posteriorly and medially to avoid a likely perforation of the filmy right atrial appendage (RAA) (Fig. 5.11) [2, 8].
8. An operator should be particularly cautious in dealing with fragile structures such as coronary sinus, right atrial appendage, and left atrial appendage. Generally, strong structures

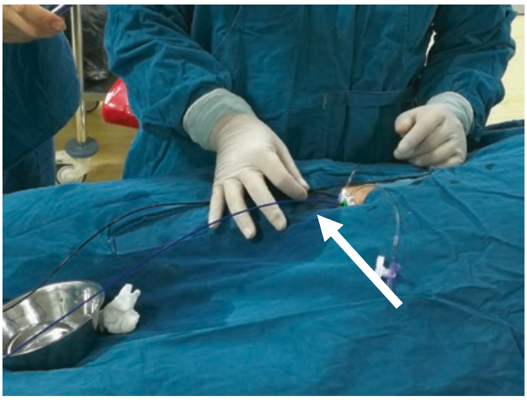

Fig. 5.9 "Short-distance advancement and slightly-hold" technique is preferred for placing catheters without fluoroscopic guidance. Using this technique, an operator holds a catheter slightly just with two fingers and advance the catheter only 1–2 cm each time, and the catheter is advanced to the target chamber by more times of manipulation

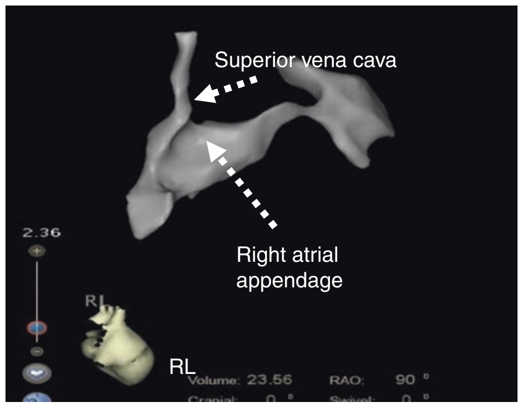

Fig. 5.11 To avoid the potential risk of perforation of right atrial appendage, right lateral view (RL) plus anterior-posterior (AP) view is recommended for placing electrodes through superior venae cava

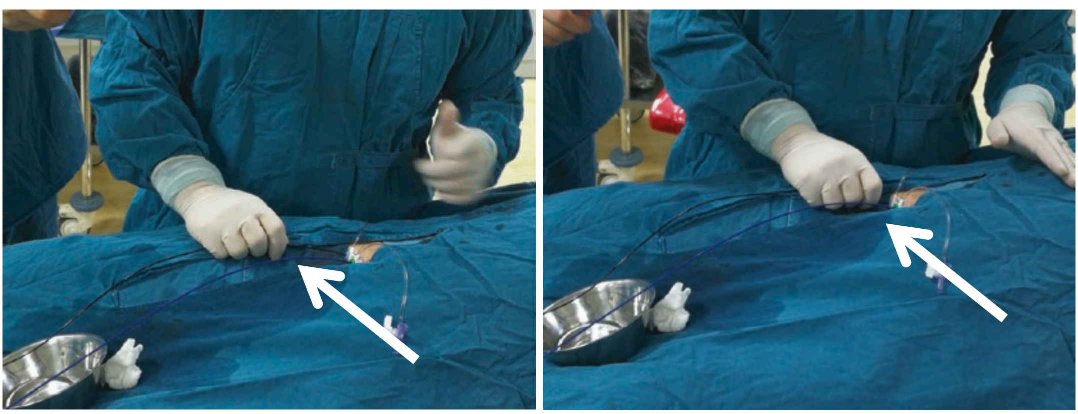

Fig. 5.10 Avoid to use "large-distance advancement and tightly-clench" technique for placing catheters without fluoroscopic guidance. Using this technique, the operator usually tightly clenches a catheter with all the fingers and advance the catheter 3–5 cm each time, and the catheter is advanced to the heart chamber by few times of manipulation

and relatively safe areas are firstly selected for catheter manipulation, model reconstruction, and revealing the anatomic location of those fragile structures.

9. Occasionally, a catheter may slip into left subphrenic venae and the electrogram recorded by the catheter presents an atrial wave plus a ventricular wave, but the amplitude is relatively small and the distal part of catheter is relatively fixed (Figs. 5.12 and 5.13).

Catheter Placement

Generally, anterior-posterior (AP) view plus right lateral (RL) view is recommended for guiding catheter insertion through vessels by three-dimensional navigation system.

Three-Dimensional Navigation System Based on Impedance Measurements

To place catheters using three-dimensional navigation system based on impedance measurements (e.g., EnSite NavX™), an operator can begin with any catheter since it is an open platform and compatible to all kinds of catheters.

Insert the catheters into the right atrium, then right ventricular apex, and the His bundle via a femoral vein, respectively. Place a catheter into the coronary sinus via a subclavian vein, a right internal jugular vein, or a femoral vein. A venous access needs to be confirmed if the coronary sinus catheter is placed by subclavian or jugular vein, which can be judged by the characteristic color of venous blood, the pressure measurement, and the interference signal of the J-shaped wire with a catheter placed in the middle of the right atrium via femoral vein [2].

It is better to advance several catheters with different curve to the heart chamber at one time and advance the catheter alternatively, which can improve the efficiency of catheter placement. An operator can change the insertion to the second catheter with a different curve, which may be helpful to find the correct vessel path when the first catheter meets obstacle somewhere in the vena cava.

Before the insertion, roughly evaluate the length required to be inserted into the sheath as follows: (1) place the tip of the catheter about three fingers cranial to the xiphoid process, which usually locates at the middle of right atrium; (2)

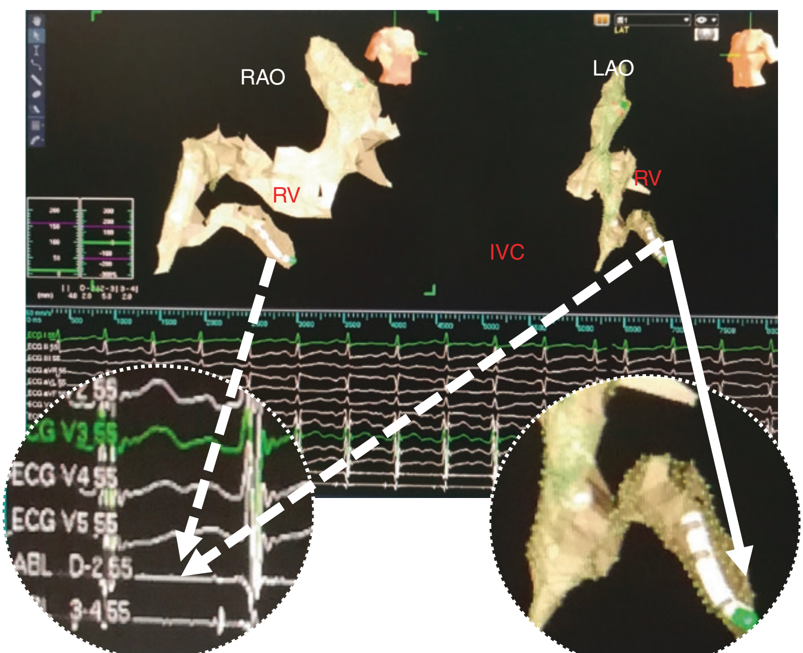

Fig. 5.12 An ablation catheter slipped into the left subphrenic venae and the catheter could not capture the ventricle. The local electrogram recorded by the catheter presented an atrial wave plus a ventricular wave, but the amplitude was small and the distal part of catheter was relatively fixed

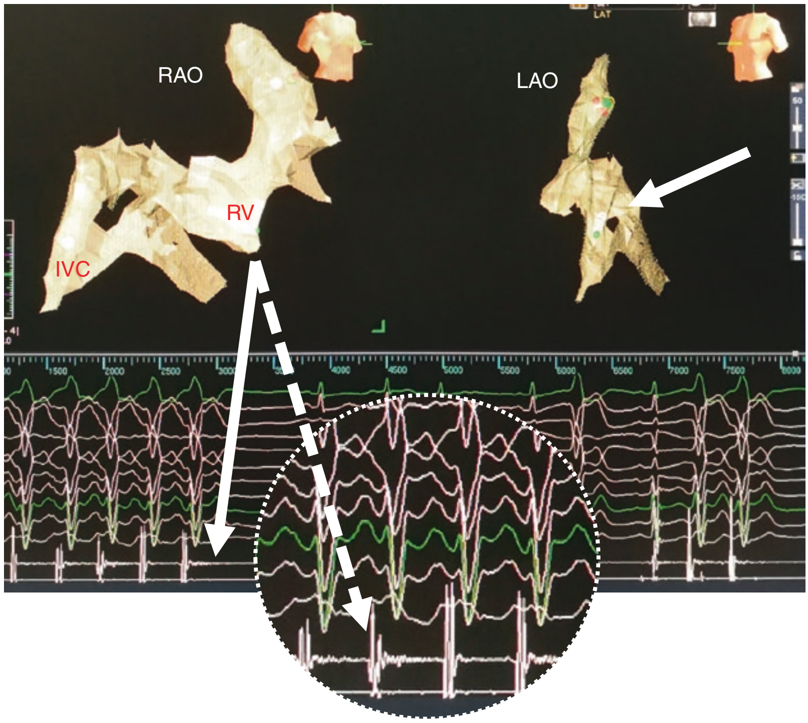

Fig. 5.13 The ablation catheter was advanced into the right ventricle and the catheter could capture the ventricle. The local electrogram also presented an atrial wave plus a ventricular wave; the amplitude was large and the distal part of catheter was free

observe and remember the distance between a catheter tail and the ankle and/or the heel of a patient (Figs. 5.7 and 5.8).

The length of all kinds of electrophysiological diagnostic catheters generally varies from 110 to 115 cm. The collector is usually about at the level of the patient's heel if the patient's stature is about 160–165 cm (Tables 5.1, 5.2, 5.3, 5.4, and 5.5).

RVA Catheter

We recommend that a catheter is inserted into the vena cava using "short-distance and slightly-hold" technique mentioned above. The operator needs to observe the moving track on the monitor and the intracardiac electrogram recorded by the catheter. Usually the track should go nearly straight to the heart chamber. Withdraw the catheter and change the direction in case of the following situations: (1) obvious resistance is still perceived with "short-distance and slightly-hold" technique; (2) the track shows a nearly right-angle turn; and (3) the anticipated intracardiac electrogram does not appear when the inserted part exceeds the length evaluated in vitro to reach the target place.

Slightly rotate the catheter when it reaches the lower part of a right atrium. Construct the model at the same time. Change the project views into RAO plus LAO view. The catheter then is advanced toward 12 o'clock in LAO view. A bigger ventricular wave and a smaller atrial wave are anticipated as the operator advances the catheter.

His Catheter

The "His" catheter can be advanced and placed similarly according to the method for placing RVA.

Coronary Sinus Catheter

Generally a coronary sinus (CS) catheter is recommended to be placed after the RVA catheter or His catheter. RAO view plus LAO view is preferred for placing CS catheter.

1. *Place CS catheter via inferior vena cava*

   Use a steerable CS catheter; place the catheter according to the following steps: (a) advance the catheter into the right atrium until catheter tip is horizontal to the tip of His catheter in cranial-caudal direction; (b) flex the tip

Table 5.1 Non-navigation ablation/diagnostic catheters of Biosense Webster Inc.

Brand and type	Catalog no.	Curve	Color	Diameter	Space (mm)	Length (cm)
Celsius® ablation (TC)						
4 mm Non-nav	D7TCAL252RT	A	Yellow	7F	2–5–2	115
4 mm Non-nav	D7TCBL252RT	B	Red	7F	2–5–2	115
4 mm Non-nav	D7TCCL252RT	C	Green	7F	2–5–2	115
4 mm Non-nav	D7TCDL252RT	D	Blue	7F	2–5–2	115
4 mm Non-nav	D7TCEL252RT	E	White	7F	2–5–2	115
4 mm Non-nav	D7TCFL252RT	F	Orange	7F	2–5–2	115
4 mm Non-nav braided tip	D8BTCDL252RT	D	Blue	8F	2–5–2	90
4 mm Non-nav braided tip	D8BTCEL252RT	E	White	8F	2–5–2	90
4 mm Non-nav braided tip	D8BTCFL252RT	F	Orange	8F	2–5–2	90
Avail® diagnostic						
Quad A curve (fixed curve)	F6QRA010RT	A	Yellow	6F	10	115
Quad F curve (fixed curve)	F6QRF010RT	F	Black	6F	10	115
Quad F curve (fixed curve)	F6QF002RT	F	Black	6F	1	115
Webster® diagnostic						
Deca (fixed curve)	F5ADP282RT	P	Gray	5F	2–8–2	60

TC thermocouple, *THR* thermistor. Biosense Webster Inc., Diamond Bar, CA, USA

Table 5.2 Three-dimensional navigation catheters of Biosense Webster Inc.

Brand and type	Catalog no.	Curve	Color	Diameter	Space (mm)	Length (cm)
Navistar® 4 mm (TC)						
4 mm Nav B curve	NS7TCBL174HS	B	Red	7F	1–7–4	115
4 mm Nav C curve	NS7TCCL174HS	C	Green	7F	1–7–4	115
4 mm Nav D curve	NS7TCDL174HS	D	Blue	7F	1–7–4	115
4 mm Nav E curve	NS7TCEL174HS	E	White	7F	1–7–4	115
4 mm Nav F curve	NS7TCFL174HS	F	Orange	7F	1–7–4	115
Navistar® ThermoCool®						
3.5 mm Nav TC B curve	NI75TCBH	B	Red	7.5F	2–5–2	115
3.5 mm Nav TC C curve	NI75TCCH	C	Green	7.5F	2–5–2	115
3.5 mm Nav TC D curve	NI75TCDH	D	Blue	7.5F	2–5–2	115
3.5 mm Nav TC F curve	NI75TCFH	F	Orange	7.5F	2–5–2	115
3.5 mm Nav TC J curve	NI75TCJH	J	Black	7.5F	2–5–2	115
ThermoCool® SmartTouch						
ST D curve	D133604IL	D	Blue	8F	1–6–2	115
ST F curve	D133605IL	F	Orange	8F	1–6–2	115
ST J curve	D133606IL	J	Black	8F	1–6–2	115
Lasso® NAV SAS						
D curve	DLN1215CT	D	Blue	7F	4.5	115
	(Ring diameter, 15 mm; annular tip diameter, 4.5F)					
PentaRay® D curve	D128211	D	Blue	7F	2–6–2	115
	(Branch tip diameter, 3F)					

TC thermocouple, *THR* thermistor. Biosense Webster Inc., Diamond Bar, CA, USA

of the CS catheter like a “7” and the tip of CS catheter is at 1–2 cm below the tip of His catheter; (c) the catheter tip is often on the line vertical to the junction of inferior vena cava with right atrium in RAO 45° view; (d) rotate the catheter clockwise and direct it toward the septum to catch the CS orifice in LAO view; (e) release the curve if the catheter tip slips into the orifice of coronary sinus; and (f) advance the CS catheter into the distal part of

Table 5.3 Ablation/diagnostic catheters of APT Medical Inc.

Brand and type	Catalog no.	Curve	Color	Diameter	Space (mm)	Length (cm)
Triguy™ ablation catheter						
Ablation 4 mm (TC)	902122	D	Blue	7F	2–5–2	85
Ablation 4 mm (THR)	902172	D	Blue	7F	2–5–2	85
Ablation 4 mm (TC)	902128	A	Yellow	7F	2–5–2	110
Ablation 4 mm (THR)	902178	A	Yellow	7F	2–5–2	110
Ablation 4 mm (TC)	902129	B	Red	7F	2–5–2	110
Ablation 4 mm (THR)	902179	B	Red	7F	2–5–2	110
Triguy™ diagnostic catheter						
Fixed curve-decapolar-CS	901533	CS	Blue	6F	2–8–2	65
Steerable decapolar-CS	901666	MPD-S	Blue	6F	2–5–2	110
Fixed curve-quadripolar-RV	901445	MPBe	Blue	6F	10	120
Fixed curve-quadripolar-RV	901446	MPA	Blue	6F	10	120
Fixed curve-quadripolar-His	901454	HIS	Blue	6F	5	120

TC thermocouple, *THR* thermistor. APT Medical Inc., Shenzhen, Guangdong, China

Table 5.4 Ablation/diagnostic catheters of St. Jude Medical

Brand and type	Catalog no.	Curve	Color	Diameter	Space (mm)	Length (cm)
Ablation (Thermocouple)						
Safire™ S–Curl	402821	Small		7F	2–5–2	115
Safire™ M–Curl	402822	Medium		7F	2–5–2	115
Safire™ L–Curl	402823	Large		7F	2–5–2	115
Therapy™ 4 mm tip	83432	Small		7F	2–5–2	110
Therapy™ 4 mm tip	83405	Medium		7F	2–5–2	110
Therapy™ 4 mm tip	83408	Large		7F	2–5–2	110
Therapy™ Cool Flex™ M	A088015	Medium		7F	0.5–5–2	110
Therapy™ Cool Flex™ L	A088016	Large		7F	0.5–5–2	110
Diagnostic catheter						
Supreme™ electrophysiology catheter	401436	NA		6F	10–10–10	120
Inquiry™ steerable diagnostic catheters	81102	NA		6F	2–5–2	110

St. Jude Medical, St. Paul, MN, USA

coronary sinus. In the second step, the position of His potential can be replaced with the peak of tricuspid annulus if the "His" potential is difficult to be recorded within 1 min. In the fifth step, adjust the catheter tip a little anteriorly or posteriorly in RAO view, or cranially or caudally in LAO view, if it cannot slip into the orifice (Figs. 5.14 and 5.15).

Occasionally, the span from CS orifice to inferior cava is relatively large and the curve of CS catheter is not long enough to reach the orifice. The operator needs to manually shape the curve so as to increase the curve size.

2. *Place CS catheter via superior vena cava*

   A catheter of fixed curve can be placed into coronary sinus according to the following steps: (a) advance the catheter into the right atrium till the catheter tip is at 1–2 cm below the tip of His catheter; (b) rotate the catheter anticlockwise and direct it toward the septum in LAO view; (c) move the catheter tip a little anteriorly or posteriorly in RAO view, or cranially or caudally in LAO view, if it cannot slip into the orifice; and (d) advance the CS catheter into the distal part of coronary sinus.

HRA Catheter

Similarly, advance and place the HRA catheter according to the method for placing RVA.

Ablation Catheter

Advance the ablation catheter according to the following method: (1) preliminarily estimate the length required to reach the target site in vitro

Table 5.5 Transseptal sheath and needles

Sheath/needle	Catalog no.	Curve	Guide wire length	Guide wire diameter	Sheath/ needle size	Dilator usable length	Sheath/needle usable length
1. Transseptal sheath							
HeartSpan™ fixed curve braided transseptal sheath[a]	FCL-160-02	55°	135 cm	0.035 in.	8.5F	65 cm	60 cm
Swartz™ braided SL transseptal guiding introducer sheath (SL1)[b]	406840	SL1	180 cm	0.032 in.	8F	67 cm	63 cm
Swartz™ braided SL transseptal guiding introducer sheath (SL1)[b]	406849	SL1	180 cm	0.032 in.	8.5F	67 cm	63 cm
FAST-CATH™ guiding introducer sheath (SR0)[b]	406844	SR0	145 cm	0.038 in.	8F	67 cm	63 cm
FAST-CATH™ guiding introducer sheath (SR0)[b]	406853	SR0	145 cm	0.038 in.	8.5F	67 cm	63 cm
Triguy™ transseptal access kit[c]	20150510	T0	150 cm	0.032 in.	8.5F	67 cm	62 cm
2. Transseptal needle							
HeartSpan™ needle[a]	FND-019-01	55°	NA	NA	21G	NA	71 cm
BRK™ needle	407200	50°	NA	NA	18G	NA	71 cm
Triguy™ needle[c]	20150510	50°	NA	NA	18G	NA	71 cm

[a]Merit Medical, South Jordan, UT, USA
[b]St. Jude Medical, St. Paul, MN, USA
[c]APT Medical Inc., Shenzhen, Guangdong, China

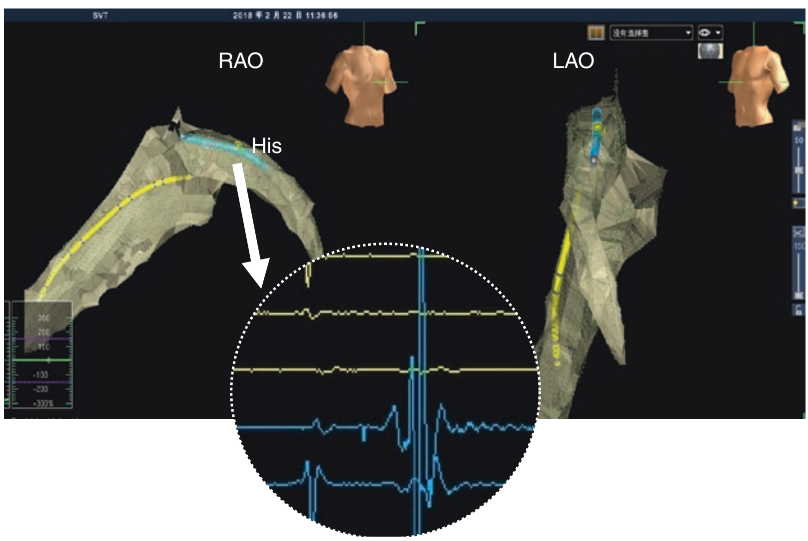

Fig. 5.14 Locate the position of His catheter or the peak of tricuspid annulus before placing coronary sinus catheter

(e.g., measuring the length from xiphoid process to the patient's heel with the ablation catheter); (2) observe the relationship between the handle of the ablation catheter and the patient's heel when the catheter tip is placed at xiphoid process in vitro; (3) slow down the advancement and observe if there is intracardiac electrogram recorded by the ablation catheter during insertion, especially when the catheter is close to the heart chamber; and (4) use the position of the collector of diagnostic catheter placed before as a reference to place an ablation catheter.

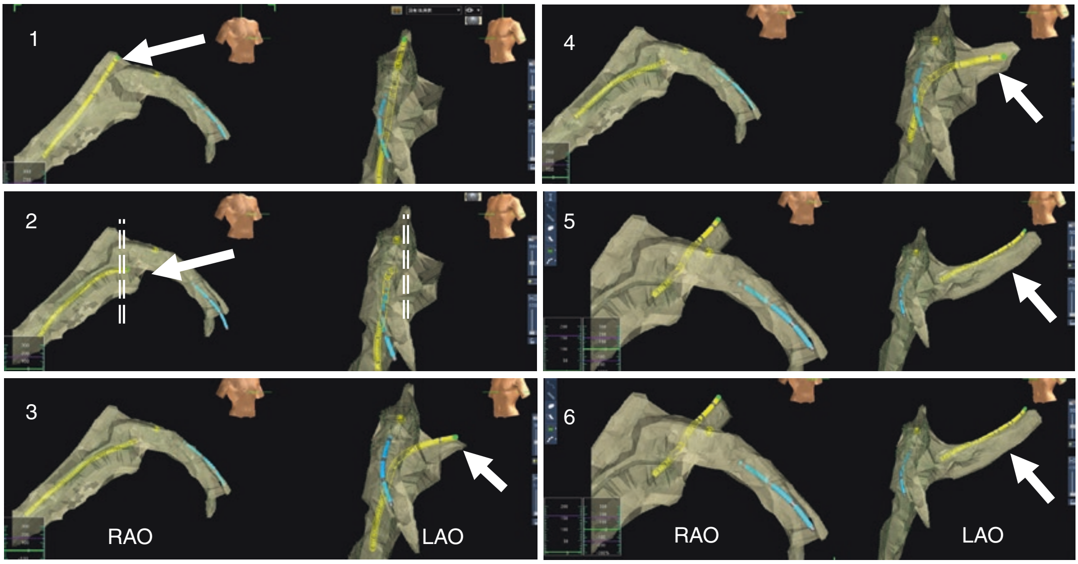

Fig. 5.15 Place coronary sinus catheter according to the following steps (1–6): flex the tip of the catheter like a "7" and place the tip of CS catheter at 1–2 cm below the tip of His catheter or the peak of tricuspid annulus; then rotate the catheter clockwise toward the septum to catch the orifice; release the curve and advance the catheter into distal part of coronary sinus

Determine the length required to be inserted into the lumen with the aid of the following tips: (1) the length of most diagnostic catheters usually varies from 110 to 115 cm; (2) the length of most ablation catheters is about 110–115 cm; (3) some ablation catheters, which are specially designed for right-sided ablation, is only 90 cm; (4) the tail of an electrophysiology catheter or a long ablation catheter (110 cm) is usually located at the patient's heel when the tip reaches the right atrium of the patient in medium stature; (5) the handle of a short ablation catheter (90 cm) is usually located at the patient's knees when the tip of ablation catheter reaches the right atrium of the patient in medium stature; and (6) usually the handle of an ablation catheter is parallel to the collector of a diagnostic catheter if they are almost the same in length (Fig. 5.16).

The shape of the moving track created on three-dimensional system usually looks like an inverted "U" in LAO view when a catheter is retrograde advanced through aortic arch via femoral artery. Withdraw the catheter if the shape looks like an "S" in LAO view (Fig. 5.17). Label the position with two or three white points when the ablation catheter reaches the lowest point in aortic root. Then the catheter can be inserted into the left ventricle as the conventional method under fluoroscopic guidance; be cautious to avoid possible injury to the aortic valve and to the coronary artery.

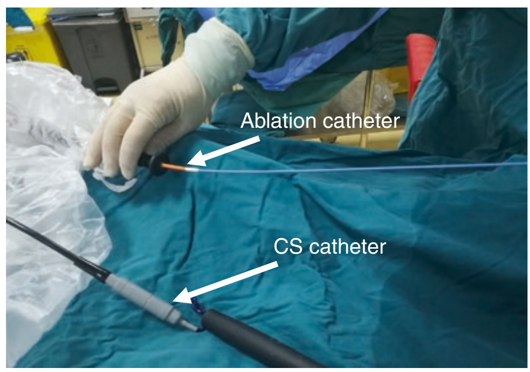

Fig. 5.16 The ablation catheter was 115 cm in length and coronary sinus catheter was 110 cm. The position of the ablation catheter could be used as a reference for judging the length of coronary catheter to be advanced

Long Sheath (e.g., SL1 Sheath)

A long sheath can be introduced according to the following three methods.

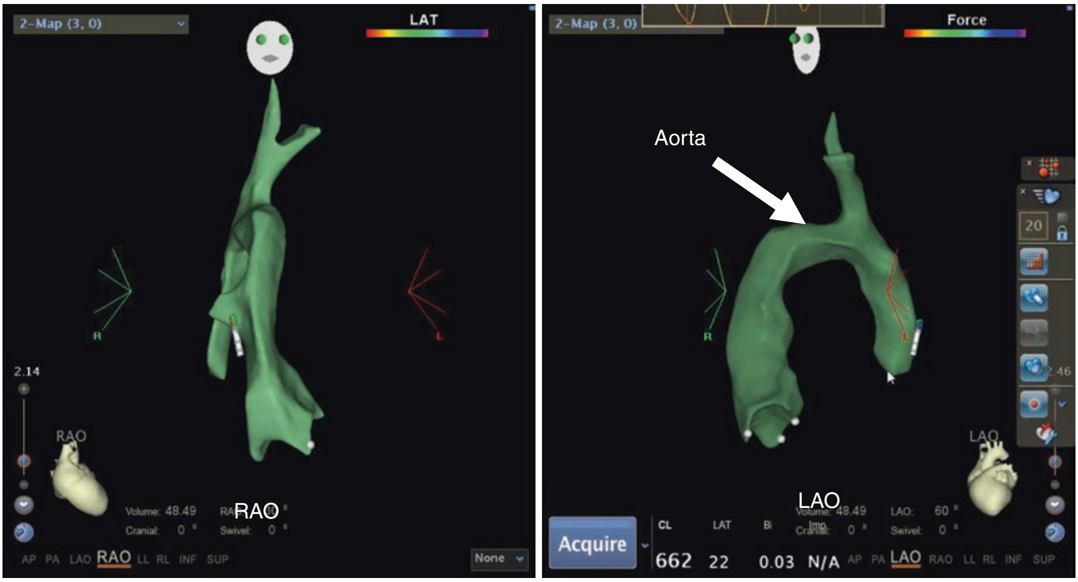

Fig. 5.17 Left anterior oblique view is recommended for advancing catheter placed via femoral artery. Aorta looks like an inverted "U" in this view

1. *Place a long sheath via an ablation catheter*
   (a) Gently insert the long guide wire, which is packed with the long sheath, the longer the better, at least 30 cm; and then advance the sheath-dilator assembly about 10–20 cm along the wire.
   (b) Withdraw the dilator and guide wire, insert an ablation catheter, and collect the catheter with three-dimensional navigation system.
   (c) Advance the ablation catheter through the long sheath till resistance is felt when the tip of ablation catheter reaches the distal curve of the long sheath.
   (d) Then hold the catheter shaft and withdraw the long sheath a little so as to display the tip of ablation catheter on the monitor of three-dimensional mapping system.
   (e) Advance the catheter to the right ventricle and flex the catheter to make a sharp curve (Fig. 5.18).
   (f) Advance the long sheath till obvious resistance is felt, which is resulted from the sharp curve.

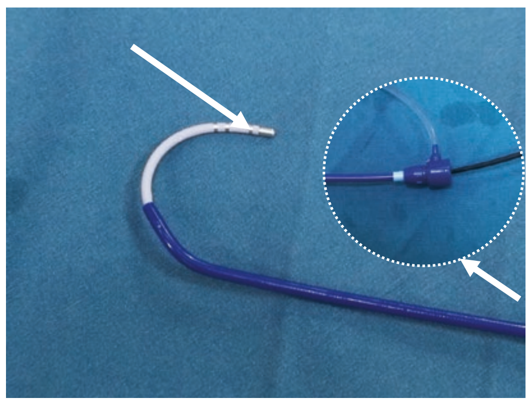

Fig. 5.18 Flex the ablation catheter to make a sharp curve in the right ventricle and then advance the sheath till obvious resistance is felt when a long sheath is guided via an ablation catheter without fluoroscopic guidance

The distance from the distal edge of the knee-cap to groin is usually about 35–40 cm, which can be used a reference for estimation during catheter placement.

In order to guarantee a safe advancement and to identify the tip's position of the sheath, observe if there are the following manifestations: the intracardiac electrogram recorded by the proximal electrodes will disappear and the image of ablation catheter will become deformed when

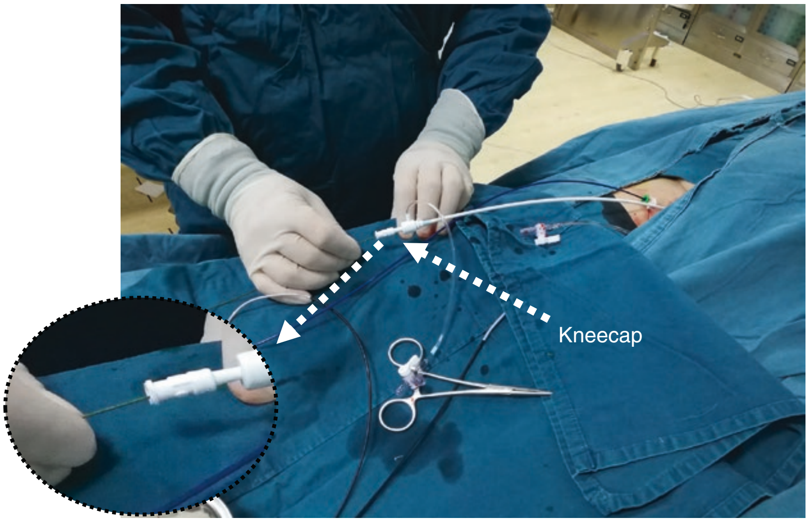

Fig. 5.19 A long sheath was placed via the packed guide wire, which is 135 cm in length. The long guide wire was advanced till the wire's tail was close to the patient's heel. Then the long sheath was advanced toward heart chamber but stopped when the sheath's end reached the distal edge of kneecap. The wire was then exchanged with an ablation catheter collected with the three-dimensional system

the tip of long sheath begins to shield the proximal electrodes.

2. *Place a long sheath via the packed guide wire*
   (a) Gently insert the long guide wire (e.g., 135 cm in length), which is packed with the long sheath, the longer the better, till the wire's tail is close to the patient's heel, and the wire's tip can almost reach the mandibular joint.
   (b) Advance dilator-sheath assembly till the tail of guide wire extends out the sheath and into the vessel about 10 cm.
   (c) Collect the tail of the guide wire with a cable, an alligator clip-to-pin cable, to the three-dimensional system.
   (d) Display the tip of the guide wire on the monitor and advance the tip of the guide wire to the heart chamber.
   (e) Advance the dilator-sheath assembly to the heart chamber and always keep the tip of the guide wire outside the assembly.

Avoid advancing the assembly straightly to the heart chamber if the heart chamber has not been reconstructed yet. An operator should estimate the length before insertion and insert the guide wire much deeper than the sheath so as to protect the tissue with the soft wire. Usually advance the long sheath toward heart chamber but slow down the advancement when the sheath's end is about at the distal edge of kneecap (Fig. 5.19).

As we all know, the usable length of most dilators is less than 67 cm, whereas the distance between the kneecap and the xiphoid process is about 70 cm in a patient in medium stature, which is about 160 cm high. Thus, the tip of the dilator is usually nearly at the orifice of inferior vena cava. Exchange the wire with an ablation catheter and advance the sheath into the heart guided by three-dimensional system.

3. *Place a long sheath via a monopolar guide wire*
   (a) Insert a monopolar guide wire into the vessel and collect the tail of monopolar wire with the three-dimensional system.
   (b) Advance the wire directly into the heart chamber till the tip of guide wire records a big atrial wave.
   (c) Advance sheath-dilator assembly to the heart chamber and always keep the tip of the guide wire outside the assembly.

The best method to introduce a long sheath is by monopolar guide wire. A common packed guide wire can be used for introducing the long sheath if there is no monopolar wire; an ablation catheter can also be used for introducing the long sheath unless obvious friction resistance is felt during the advancement.

Three-Dimensional Mapping System Based on Magnetic Location Technology

As for placing catheters guided by magnetic location technology (e.g., Carto™) and without fluoroscopy, a sensor-based catheter, which is usually an ablation catheter, needs to be used firstly for model reconstruction; choose an appropriate ablation catheter if the ablation target (e.g., AVNRT) is definite according to ECG characteristics; choose a medium catheter which is suitable for most kinds of situation if the ablation target is not definite.

In our center, the size of an ablation catheter is determined according to the following principles: (1) choose a big-curve catheter (e.g., F curve, 4 mm, Navistar) usually for the ablation of AVNRT; (2) choose a medium-curve catheter for unknown type of SVT and use a SL1 sheath for increasing the span if the final diagnosis is AVNRT or right-sided AVRT.

Locate the anatomic marks in vitro and label the position on three-dimensional model with two or three blue points before inserting the ablation catheter (e.g., xiphoid process, three-finger width over xiphoid process, presternum).

Advance the ablation catheter into the heart with the aid of three-dimensional navigation system and the marks mentioned above.

Again, label 2–3 key points on the model with the ablation catheter before the insertion of diagnostic catheters. Those points include (1) the His potential or the peak of tricuspid valve if the "His" potential is not easy to be detected within 10 s and (2) the lowest point of tricuspid valve.

The methods to place diagnostic catheters such as HRA, RVA, CS, and His are similar to the method using electric field navigation system. However, it is recommended to reconstruct coronary sinus with the ablation catheter first (Fig. 5.20). A soft ablation catheter (4 mm Navistar®, Biosense Webster Inc., Diamond Bar, CA, USA) is preferred for the reconstruction and further ablation in patients with SVT.

As we all know, the magnetic field is limited to the area nearby a heart chamber. As an operator places catheters without fluoroscopic guidance, the moving track cannot be displayed on the monitor if the catheters are below the umbilicus area. Hence, an operator must be

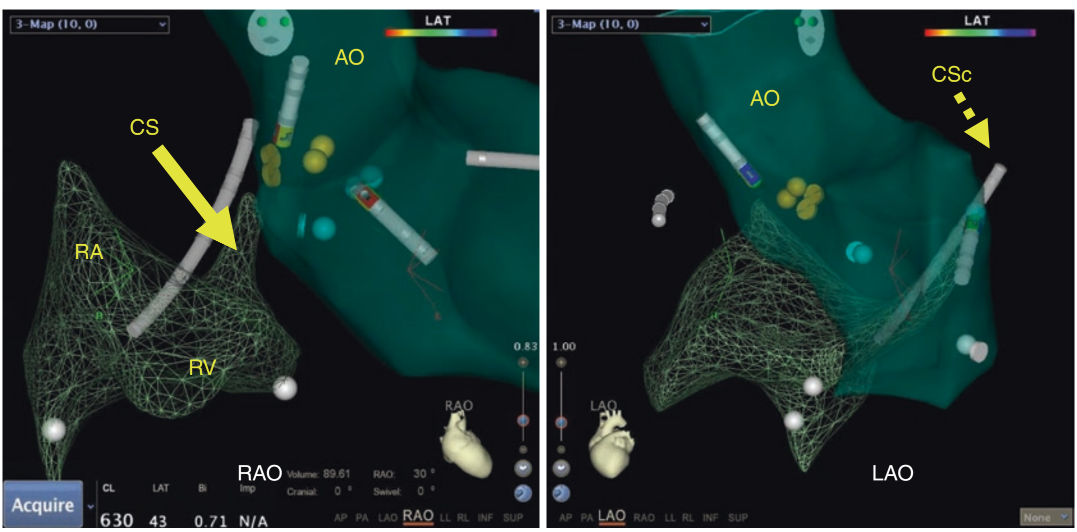

Fig. 5.20 The model was reconstructed during zero-fluoroscopic ablation of left accessory pathway using Carto™ system. Coronary sinus (CS) was reconstructed first with a soft ablation catheter. *CSc* coronary sinus catheter, *AO* aorta, *RA* right atrium, *RV* right ventricle, *RAO* right anterior oblique view, *LAO* left anterior oblique view

Fig. 5.21 Snapshot tool was used for guiding catheter placement. The red solid arrow showed a wrong direction and the dotted arrow indicated a correct direction in right later view when the catheter was about at the collection of two common iliac veins

particularly gentle and patient, and avoid rapid advancement before he/she can see the moving track of a catheter. However, as for a sensor-based ablation catheter, snapshot tool could help us adjust the direction in AP view plus RL views (Fig. 5.21).

At times, a catheter, especially RVA, will slip into vascular bifurcations if the insertion is guided by EnSite system. However, it is not the case if the insertion is guided by Carto system; the reason might be due to the first introduced ablation catheter, which can act as a sliding rail. Anyway, it needs more time and patience to insert catheters into heart chamber using magnetic field system than it does using electric field system.

Model Reconstruction

Preparation Before Model Reconstruction

Tell the patient to breathe smoothly and avoid body movement if the patient is conscious.

Remember to remove any metal guide wire inside the heart chamber before model reconstruction when electric field navigation system (e.g,. EnSite NavX™) is used.

System Reference and Positional Reference

EnSite System

1. System reference

   Traditionally, the system reference patch is placed on the patient's abdomen according to the default setting. However the patient's subscapularis is better for placing the patch if the patient is very obese and with vigorous respiration movements.

2. Positional reference

   Generally, external skin patch can be utilized as the reference during vessel puncture and right-sided mapping, whereas the coronary sinus (CS) catheter is recommended to be used as a reference during left-sided mapping if the position of CS catheter is stable [2]. Whatever you do, you need to be alert to the dislodgment of the positional reference, especially when intracardiac reference is used.

   It is better to leave a shadow of the coronary sinus catheter using system reference as positional reference; then leave the second shadow of the coronary sinus catheter using coronary sinus catheter as positional reference. These two shadows may help the operator to restore the original position of the CS catheter.

Carto System

There are three patches on the back and three others on the chest, which surround the heart. Positional reference usually utilizes the system reference.

Respiration Compensation

EnSite System

Perform an initial optimization and respiration compensation just before catheter placement. The second optimization and respiration compensation is recommended for model reconstruction after all the catheters are at position. Occasionally the third respiration compensation is required if the patient's respiration pattern changes obviously or an ablation site is at a high-risk area (e.g., near the His region). Operators should recheck the exact location of important markers such as the His bundle before power delivery.

Carto System

As for atrial fibrillation, reconstruct the left atrium and appendage with the respiratory gating technique (Accuresp algorithm, Biosense Webster, Diamond Bar, CA). During the training of respiration, talking with the patient may be helpful for achieving a successful training whereas intensified respiration is not recommended.

Model Reconstruction

Focus on the Targeted Area

Just reconstruct the virtual geometry of targeted areas. The targeted areas can be judged by electrophysiological analysis or after a rough mapping [2].

A relatively detailed reconstruction of right cardiac chamber is required if transseptal catheterization (TSP) is to be performed without fluoroscopic guidance. A retrograde approach via a femoral artery is recommended for arrhythmias originating in the left heart chamber. Although TSP can be performed without fluoroscopic guidance, it is a little time consuming and needs more expense for SVT ablation.

Usually, it is not necessary to reconstruct a full virtual geometry of the heart chamber. Just focus on the targeted area, and only relevant critical landmarks need to be labeled.

Selective geometry reconstruction focused on the targeted area will save procedure time and improve efficiency. Many novices and experienced operators have the tendency to reconstruct the whole cardiac chamber, including many unnecessary areas, when they begin to perform zero-fluoroscopic ablation [2].

Arrange Proper Reconstruction Sequence

As mentioned above, an operator should be particularly cautious in dealing with fragile structures such as coronary sinus, and right and left atrial appendage. Generally, stronger structures and safer areas are reconstructed firstly so as to reveal the anatomic location of those fragile structures. As for the reconstruction of left atrium: (1) reconstruct the inferior part firstly and then the superior part and (2) reconstruct the posterior wall firstly and then the anterior wall when it comes to superior part (Figs. 5.22 and 5.23).

The reconstruction sequence for an electrophysiological study or a right-sided cardiac mapping is recommended as follows: (1) inferior vena cava; (2) bottom of right atrium; (3) tricuspid annulus or His position; (4) right ventricle; (5) posterior part of high right atrium; and (6) superior vena cava (Fig. 5.24).

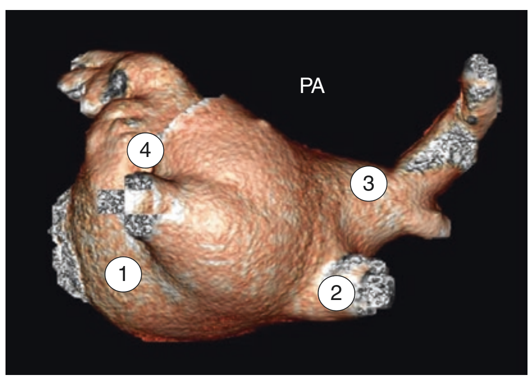

Fig. 5.22 The reconstruction sequence (1–4) of left atrium recommended for a novice was labeled in posterior-anterior (PA) view. Usually reconstruct the bottom area firstly and finally reconstruct the fragile atrial appendage

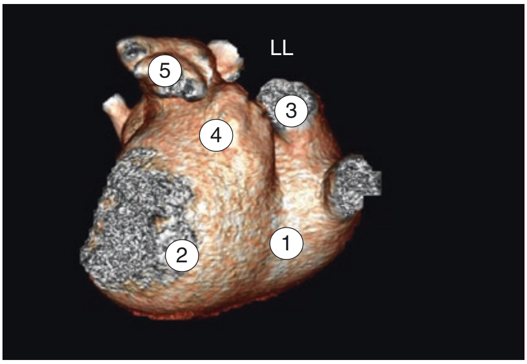

Fig. 5.23 The reconstruction sequence (1–5) of left atrium (LL) recommended for a novice was labeled in left lateral view. Reconstruct the bottom area firstly and finally reconstruct the fragile atrial appendage

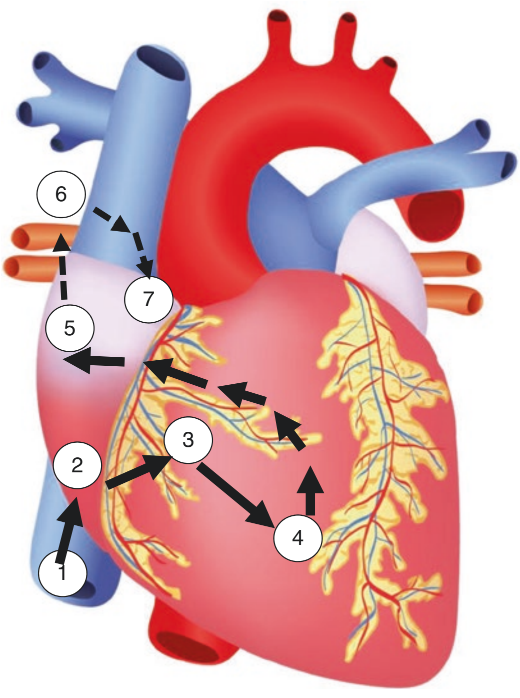

Fig. 5.24 As to an electrophysiological study or right-sided ablation, the reconstruction sequence (1–7) of the heart chamber for a novice was labeled in anterior-posterior view. The catheter was advanced and placed according to the following sequence: inferior vena cava, the tricuspid annulus, right ventricle, His bundle, high right atrium, superior vena cava, and atrial appendage if necessary

Keep Key Sites of Vessel Path

Delete the unimportant part of the track recorded during catheter insertion. Keep the key sites of the path, which will help to guide the following manipulation. Usually, keep those parts of the vena cava at where it is easy to slip into bifurcations during catheter insertion. Keep the aorta arch to avoid an unexpected insertion into the carotid artery.

Make Reconstruction by Stages

An operator needs to consider the procedure time, the patient's compliance and tolerance, and whether the patient is conscious or not before model reconstruction. Sometimes it is better to reconstruct the model by stages when the patient is conscious and cannot keep stationary in certain duration.

During the ablation of atrium fibrillation, just reconstruct a detailed model of the left pulmonary vein antrum (PVA) plus several points of right pulmonary vein for the ablation of left PVA; then reconstruct a detailed right PVA plus several points of left pulmonary vein for the ablation of right PVA.

Use a softer mapping catheter firstly (e.g., Lasso® or Pentaray®) and then a stiffer catheter.

Soft ablation catheter such as 4 mm Navistar® or Safire® can be considered for model reconstruction if an ablation catheter is used firstly.

Select Appropriate Project Views

Appropriate views may ease operators and save procedure time. The following project views are optional for zero-fluoroscopic ablation technique:

1. Catheter placement: anterior posterior (AP) plus right lateral (RL) views.
2. Atrial flutter: RAO plus LAO views, and turn over to reveal the inferior part of the model in LAO view, which facilitates to display the isthmus line better.
3. Right ventricular outflow tract (RVOT) arrhythmias: RAO plus LAO views.
4. Supraventricular tachycardia (SVT): RAO plus LAO views.
5. Atrial fibrillation: (a) left pulmonary vein antrum, AP or anterior posterior (PA) plus left lateral (LL) views; (b) right pulmonary vein antrum, AP or PA plus right lateral (RL) views.

Set Proper Display Pattern

A proper display pattern of a model can improve procedural efficiency.

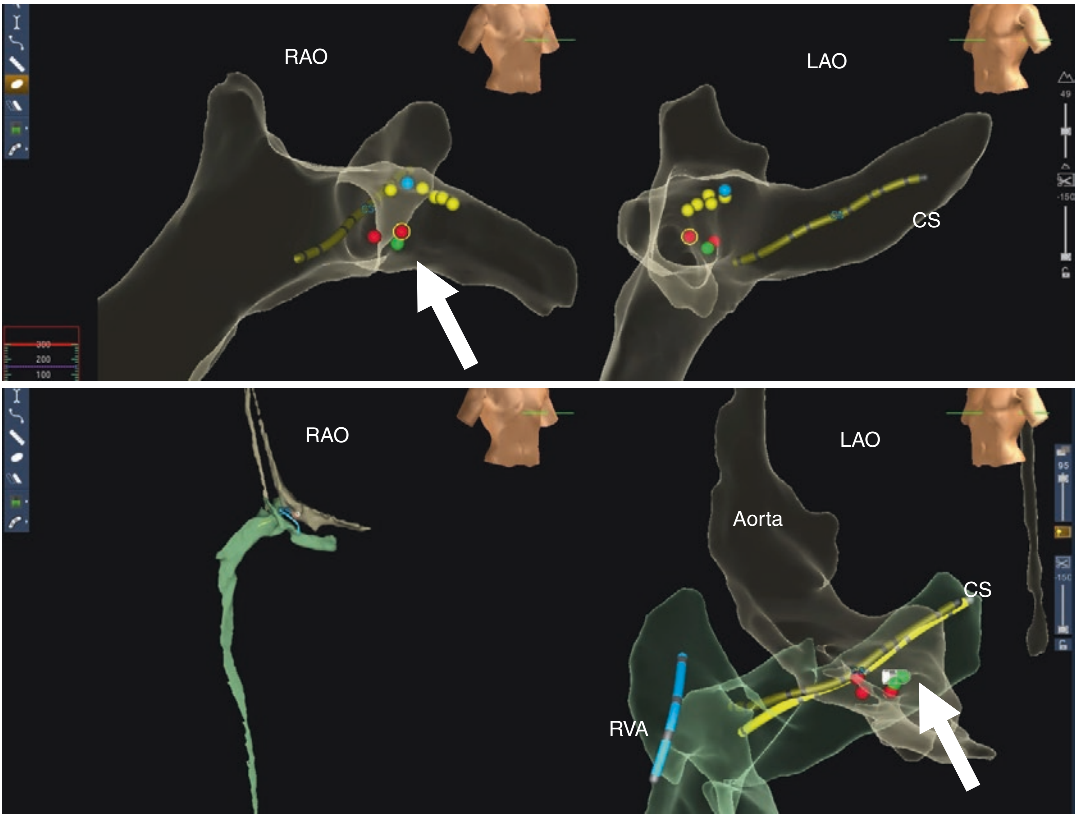

Fig. 5.25 The model was set in edge enhancement and surface translucency, which was easy for the operator to see the catheter's shadows and the labeled dots

Set the model in mesh pattern for the ablation of right ventricular outflow tract (RVOT) arrhythmias, which will be convenient to observe the distance between the tip of ablation catheter and the site of earliest activation.

Display the model in semitransparency when an operator performs the first antrum ablation in atrial fibrillation. Close the semitransparent pattern when the operator performs the second antrum ablation. Usually semitransparent pattern helps an operator to see the ablation points clearer during the first antrum ablation whereas the marked points in the first antrum interfere the display of second antrum in semitransparency.

Set the model in edge enhancement and surface translucency at the maximum, which will make the model look like a sketch, during the ablation of SVT when EnSite NavX™ is used (Fig. 5.25) [2].

Mark the Key Points by Default Setting

Mark the key points during model reconstruction. It is better to mark different anatomic structures with a set of colors by default in a lab. We generally mark the annulus, the bottom of aortic root, with white dots, His area with yellow dots, the largest His potential with blue dot, appendage with light red color, ideal target with green dots, and ablation points with maroon dots [2].

References

1. Calkins H, et al. Radiation exposure during radiofrequency catheter ablation of accessory atrioventricular connections. Circulation. 1991;84:2376–82.
2. Wang Y, et al. Ablation of idiopathic ventricular arrhythmia using zero-fluoroscopy approach with equivalent efficacy and less fatigue: a multicenter comparative study. Medicine (Baltimore). 2017;96:e6080. https://doi.org/10.1097/MD.0000000000006080.

3. Ruiz-Granell R, et al. Implantation of single-lead atrioventricular permanent pacemakers guided by electroanatomic navigation without the use of fluoroscopy. Europace. 2008;10:1048–51. https://doi.org/10.1093/europace/eun139eun139.
4. Casella M, et al. "Near-zero" fluoroscopic exposure in supraventricular arrhythmia ablation using the EnSite NavX mapping system: personal experience and review of the literature. J Interv Card Electrophysiol. 2011;31:109–18. https://doi.org/10.1007/s10840-011-9553-5.
5. Gist K, Tigges C, Smith G, Clark J. Learning curve for zero-fluoroscopy catheter ablation of AVNRT: early versus late experience. Pacing Clin Electrophysiol. 2011;34:264–8. https://doi.org/10.1111/j.1540-8159.2010.02952.x.
6. Bulava A, Hanis J, Eisenberger M. Catheter ablation of atrial fibrillation using zero-fluoroscopy technique: a randomized trial. Pacing Clin Electrophysiol. 2015;38:797–806. https://doi.org/10.1111/pace.12634.
7. Scaglione M, et al. Zero-fluoroscopy ablation of accessory pathways in children and adolescents: CARTO3 electroanatomic mapping combined with RF and cryoenergy. Pacing Clin Electrophysiol. 2015;38:675–81. https://doi.org/10.1111/pace.12619.
8. Chen G, et al. Zero-fluoroscopy catheter ablation of severe drug-resistant arrhythmia guided by EnSite NavX system during pregnancy: two case reports and literature review. Medicine (Baltimore). 2016;95:e4487. https://doi.org/10.1097/MD.0000000000004487.
9. Gaita F, Guerra PG, Battaglia A, Anselmino M. The dream of near-zero X-rays ablation comes true. Eur Heart J. 2016;37:2749–55. https://doi.org/10.1093/eurheartj/ehw223, pii: ehw223.
10. Yang L, et al. Meta-analysis of zero or near-zero fluoroscopy use during ablation of cardiac arrhythmias. Am J Cardiol. 2016;118:1511–8. https://doi.org/10.1016/j.amjcard.2016.08.014, pii: S0002-9149(16)31374-1.
11. Fernandez-Gomez JM, et al. Exclusion of fluoroscopy use in catheter ablation procedures: six years of experience at a single center. J Cardiovasc Electrophysiol. 2014;25:638–44. https://doi.org/10.1111/jce.12385.