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Original Article

Femoral artery puncture at the level of the superior border of the pubic tubercle

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Abstract: Here, we explored the feasibility of performing a femoral artery puncture (FAP) at the level of the superior border of the pubic tubercle (SBPT). A total of 202 Chinese Han patients who were scheduled for urgent or elective FAP in our hospital were recruited from August 2012 to June 2013. FAP was performed under transfemoral arteriography. Demographic and anatomical data of these patients were obtained. The ratios of the intersection points of the femoral artery with landmarks [horizontal lines through SBPT (SBPT'), the center of femoral head (C'), the inferior border of the femoral head-(IBFH'), and inguinal skin crease (SC)] were analyzed in different positions of the lines I' [a straight line parallel to the connecting line of the anterior superior iliac spine (ASIS) and SBPT was drawn through the lowest point of the inferior epigastric artery (IEA) loop] and B' (horizontal line through femoral artery bifurcation). The lines SBPT' and C', rather than IBFH' and SC, were considered to be the landmarks for body mass index (BMI) comparison owing to the higher ratiosof the intersection pointsdistal to I' and proximal to B'than IBFH' and SC. Further, female patients with intersection points proximal to I' and B' had higher BMI. A significant linear relationship was found between DSBP (distance between SBPT and the intersection point of the femoral artery with SBPT') and DASSB (distance between ASIS and SBPT), which was superior in men than in women. The FAP could be performed safely on the level of SBPT. Moreover, BMI might affect the location of IEA loop in female patients.

Keywords: Femoral artery puncture, superior border of pubic tubercle, body mass index, landmarks

Introduction

Femoral artery puncture (FAP) is a diagnosis and treatment technology by injecting a gas or contrast agent into the body cavity for imaging, or injecting the drug into the body cavity [1]. FAP is suitable for the diagnosis of vascular lesions, examination of blood supply and the relationship with vital blood vesselsin some of the tumor before surgery, postoperative follow-up of vascular lesions and interventional radiotherapy of vascular lesions [2]. FAP is the most commonused for method of vascular access by cardiologists, radiologists, interventional neurologists, and vascular surgeons for manykinds of coronary and peripheral diagnostic and interventional procedures [2]. However, there is a considerable risk of local vascular complications following FAP [3], such as hematoma, pseudoaneurysm, formation of arteriovenous fistula and retroperitoneal hemorrhage [4]. In particular, the inappropriate puncture site is usually associated with high morbidity, mortality, and health care costs [5-7]. Therefore, it is important to select the landmark precisely and to puncture in an appropriate location.

The femoral artery can be located by various technologies methods, including traditional palpation, ultrasonography and fluoroscopy-guided access. The femoral artery was palpated according to the inguinal skin crease, maximal impulse point and bony landmarks. The palpation of the arterial pulse was considered as the most reliable landmark forlocalizing the arterial access site [8]; however, it was a challenge in patients with obesity or hypotension and patients with a prior hematoma or excessive scar tissue formation whose common femoral artery pulse may be diminished [9]. Ultrasound guidance could improve the secondary outcomes of the common femoral artery (CFA) puncture when compared to palpation-guided puncture, and the technical success and complication ratesseemed to be lower [10]. As reported, ultrasound mapping of the CFA before endovascular intervention could eliminate discrepancies between the incidence of pseudoaneurysm formation and the frequency of arterial puncture [11]. Fluoroscopic guidance was also widely recommended to reduce complications, on the basis of the observation that 65% femoral artery bifurcations occurred below the inferior border of the femoral head [12-14]. Despite the various advantages and limitations, these methods aimed to reduce vascular complications [15].

Among all arterial puncture sites, the CFA has remained the primary access site for coronary and peripheral diagnostic, and interventional procedures [16]. However, over 98% patients had a bifurcation at or below the center of the femoral head, and only 46% arterial punctures were performed atan ideal site [17]. Currently, it has been recommended that the ideal puncture site should be located below the inguinal ligament (IL) to avoid "high sticks", and above the CFA bifurcation to avoid "low sticks". As reported, the CFA access between the center of the femoral head and acetabulum would prevent "low sticks" in 98.5% patients [17]; a target zone located 5-14 mm below the center of the femoral head was also suggested [14]. However, the CFA access in these ideal puncture sites could be accomplished only in 92% patients, and "high sticks" and "low sticks" occurred in 2.7% and 3.7% patients, respectively [18].

Other landmarks have been used in clinical practice forartery puncture. For example, the inguinal skin crease has been used as a landmark for femoral puncture; this site is distal to the bifurcation of the CFA, making this approach more likely to puncture the superficial femoral artery or deep femoral artery [19]. In addition, a constant separation of 2 cm between the inferior border of the femoral head and the bifurcation of the CFA was also used as a landmark [20]. We assumed that the superior border of the pubic tubercle (SBPT) could also be regarded as a landmark to locate the femoral artery. In this study, FAP was performed at the level of SBPT by analyzing the anatomic relationship between the femoral artery and peripheral anatomical structures, as well as the relationships between thebody mass index (BMI) and anatomical structures surrounding the femoral artery. This method would provide a reference for cardiologists, radiologists, interventional neurologists as well as vascular surgeons for performing interventional therapy.

Patients and methods

Patients

A total of 114 Chinese Han men (age 62.5 ± 17.4 years) and 88 women (age 58.2 ± 14.3 years) who were scheduled for urgent or elective FAP in the 3rd Affiliated Hospital of Harbin Medical University were recruited in this study from August 2012 to June 2013. Inclusion criteria included an age of 18 years or older, and patients who would undergo urgent or elective FAP in the process of transcatheter arterial chemoembolization or coronaryangiography with transfemoral arteriography. Patients who had a vascular or nonvascular surgery at the site of the CFA or inguinal malformation were excluded. This study was approved by the Institutional Review Board of the 3rd Affiliated Hospital of Harbin Medical University, and the informed consent was obtained from all patients.

Demographic and clinical data of these patients were collected, including BMI and radiographic data. The anatomical data were acquired using an Innova 4100 cardiovascular imaging system (GE Healthcare, Milwaukee, WI), and then transmitted to ST-PACS CD Medical V3.1 Workstation (CREALIFE, Beijing, China) for analysis. The angiograms were analyzed by two physicians.

FAP and measurements

Patients were placed on a digital subtraction angiography examination bed in a supine position; then, femoral arterial cannulation using indwelling introducer sheaths was performed by the cardiologists or radiologists. A caudal tube was used for fluoroscopy in an anteroposterior projection, and the pubic tubercle (PT) was manifested. After the palpation of the PT, the fingers palpated cranially to search for the SBPT, and then, were kept motionless for the anteroposterior projection fluoroscopy. During this process, the location of the SBPT was

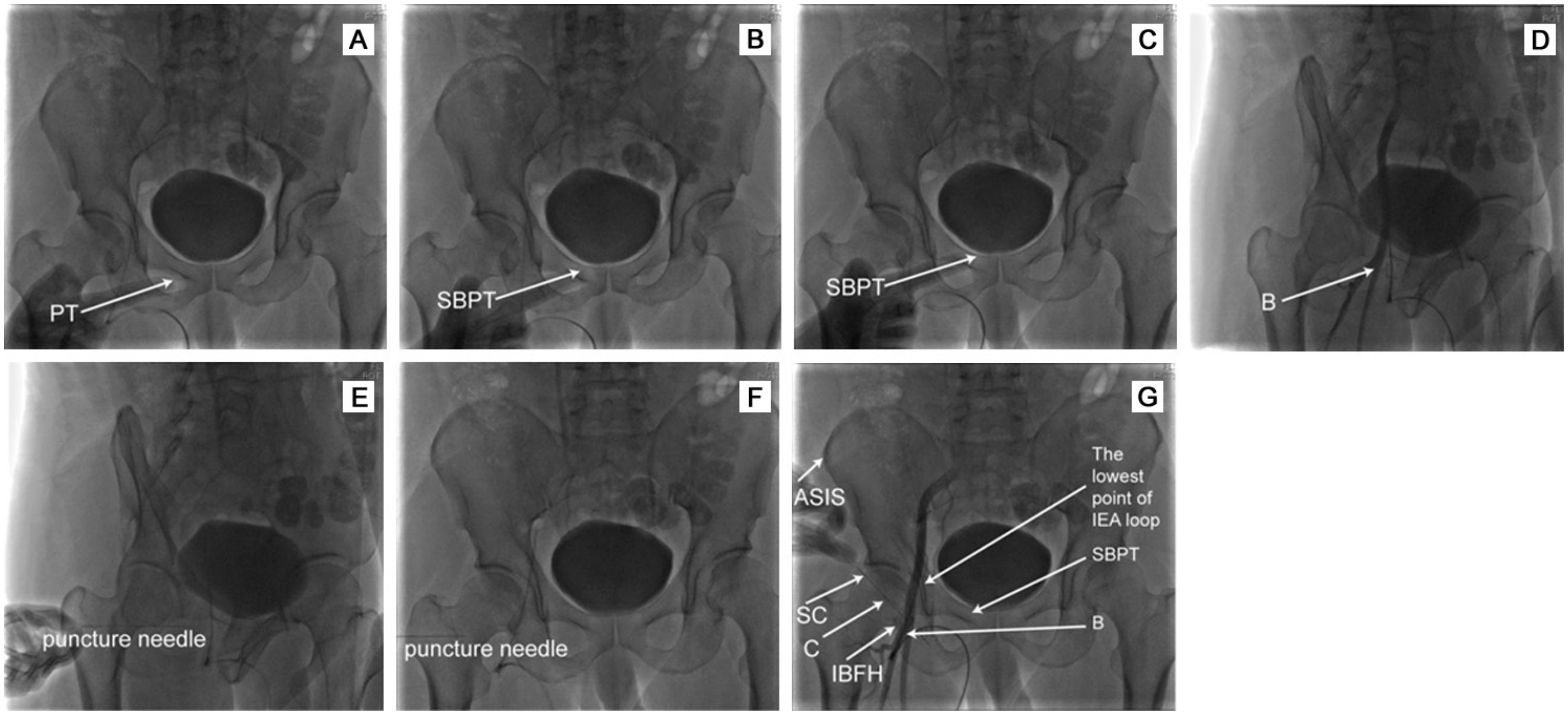

Figure 1. The locations of anatomical landmarks under femoral arteriography. A: The location of pubic tubercle (PT); B: The location of superior border of pubic tubercle (SBPT); C: The location of SBPT in an anteroposterior projection; D: The location of the femoral artery bifurcation (point B) in a right anterior oblique projection; E: The puncture needle at point B horizontally in the right anterior oblique projection; F: The puncture needle at point B horizontally in the anteroposterior projection; G: Femoral arteriography in the anteroposterior projection when the puncture needle was inserted along the inguinal skin crease (SC).

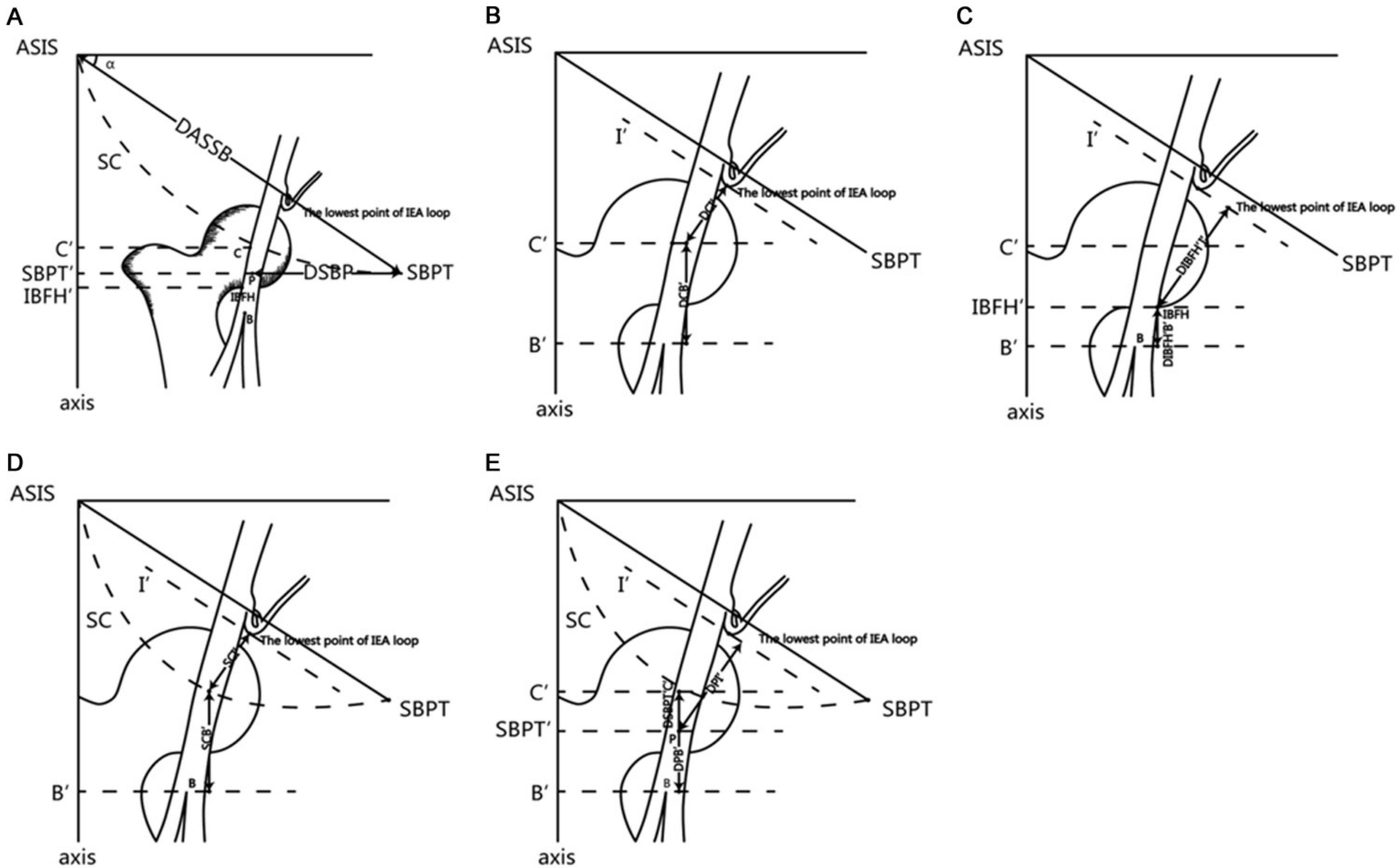

Figure 2. The schematic diagrams of femoral artery puncture on the level of SBPT. A: The distances between ASIS and SBPT and the horizontal distance between the point P (the intersection points of femoral artery and SBPT') and SBPT in the anteroposterior projection; B-E: The distances between the intersection points of four landmarks (C', IBFH', SC, and SBPT') with the femoral artery and I', B'. SBPT, superior border of pubic tubercle; point B, femoral artery bifurcation; SC, inguinal skin crease; ASIS, anterior superior iliac spine; point C, the center of femoral head; IBFH, inferior border of femoral head; IEA, inferior epigastric artery; point P, the intersection points of femoral artery and SBPT'; DASSB, the distance between ASIS and SBPT; DSBP, distance between SBPT and the intersection point of femoral artery with SBPT'; ∠α, the angle between the connecting line of bilateral ASIS and the connecting line of ASIS and SBPT; I', a straight line parallel to the connecting line of ASIS and SBPT through the lowest point of IEA loop; the horizontal lines drawn through point B, point C, SBPT and IBFH were labeled as B' and C', SBPT' and IBFH'; DSBPT'C', the perpendicular distance between the SBPT' and C'; DPI' and DPB', the distances between point P with I' or B', DC'I' and DC'B', the distances between line C' with I' or B'; DIBFH'I' and DIBFH'B', the distances between line IBFH' with I' or B'; SCI' and SCB', the distances between line SC with I' or B'.

Table 1. Summarization of measurements of femoral arteriography

Variable	Min	Max	*Mean ± SE*
DASSB	125.00	170.00	147.02 ± 0.589
DSBP	22.00	53.00	38.60 ± 0.429
∠α	35.00	52.00	44.83 ± 0.243
DSBPT'C'	-15.00	11.00	-5.71 ± 0.326
DPI'	-20.79	0.00	-10.95 ± 0.374
DPB'	-20.00	57.00	14.30 ± 0.959
DC'I'	-23.09	4.53	-9.58 ± 0.440
DC'B'	-10.00	60.48	18.25 ± 0.957
DIBFH'I'	-44.01	-11.57	-28.03 ± 0.517
DIBFH'B'	-29.00	40.00	-0.24 ± 0.922
SCI'	-46.92	0.05	-29.20 ± 0.768
SCB'	-31.00	44.00	-1.34 ± 1.034

SBPT, superior border of pubic tubercle; PT, pubic tubercle; point B, femoral artery bifurcation; SC, inguinal skin crease; ASIS, anterior superior iliac spine; point C, the center of femoral head; IBFH, inferior border of femoral head; IEA, inferior epigastric artery; point P, the intersection points of femoral artery and SBPT'; DASSB, the distance between ASIS and SBPT; DSBP, distance between SBPT and the intersection point of femoral artery with SBPT'; ∠α, the angle between the connecting line of bilateral ASIS and the connecting line of ASIS and SBPT; I', a straight line parallel to the connecting line of ASIS and SBPT through the lowest point of IEA loop; the horizontal lines drawn through point B, point C, SBPT and IBFH were labeled as B' and C', SBPT' and IBFH'; DSBPT'C', the perpendicular distance between the SBPT' and C'; DPI' and DPB', the distances between point P with I' or B', DC'I' and DC'B', the distances between line C' with I' or B'; DIBFH'I' and DIBFH'B', the distances between line IBFH' with I' or B'; SCI' and SCB', the distances between line SC with I' or B'.

recorded (**Figure 1A-C**). Femoral arteriography was performed in a right anterior oblique projection, and the horizontal line through the femoral artery bifurcation (point B) was determined and labeled by a puncture needle. Then, the needle was kept motionless and its location was reconfirmed by fluoroscopy in the anteroposterior projection (**Figure 1D-F**).

An introducer needle was inserted along the inguinal skin crease (SC) as a radiographic marker. Femoral arteriography was performed under anteroposterior projection fluoroscopy, and the following anatomical structures in the anteroposterior projection were revealed: (1) the anterior superior iliac spine (ASIS), (2) SBPT, (3) center of the femoral head (point C), (4) the inferior border of femoral head (IBFH), (5) SC, (6) point B (**Figure 1G**), (7) the lowest point of inferior epigastric artery (IEA) loop (**Figure 1G**), and (8) the angle between the connecting line of the bilateral ASIS and the connecting line of the ASIS and SBPT) (∠α, **Figure 2A**). Furthermore, the horizontal lines drawn through point B, point C, SBPT, and IBFH were labeled as B', C', SBPT', and IBFH', respectively (**Figure 2A**). The distance between ASIS and SBPT (DASSB) and the horizontal distance between the point P (the intersection points of the femoral artery and SBPT') and SBPT (DSBP) were measured in the anteroposterior projection (**Figure 2A** and **2B**). A straight line parallel to the connecting line of the ASIS and SBPT was drawn through the lowest point of the IEA loop and labeled as I'. The intersection points of the femoral artery with the landmarks (the horizontal lines C', IBFH', SC, and SBPT') were recorded and the vertical distances between the intersection points and I' or B' were calculated (DC'I' or DCB', DIBFH'I' or DIBFH'B', SCI' or SCB', DPI' or DPB', **Figure 2B-E**). The intersection points distal to I' or B' and proximal to I' or B'were recorded as '-' and '+', respectively.

Statistical analyses

The distances between different anatomical locations areshown as mean ± standard error (SE), and other measurement data are presented as themean ± standard deviation (SD) and analyzed by SAS PROC MEANS, which was used to calculate most of the statistics for one or more numeric variables in a data set. Meanwhile, the variance analysis and parameter estimation were calculated by SAS PROC Analysis of Variance (ANOVA) which was used to evaluate the effect of different test conditions in normal volunteers and SAS PROC Regression Analysis (REG) which was used to estimate the adjusted effects of depression and anxiety on the cumulative number of days of exacerbations and hospitalizations. All the above calculations were performed on SAS 9.1 with (SAS Institute, Carry, NC, 2003).

Results

The results of measurements

The distances between different anatomical locations were measured based on the basis of **Figure 2** (**Table 1**). The distance of DSBPT'C' was -5.71 ± 0.326 cm, indicating that the DSBP was close to the femoral head center. When SBPT' and C' were considered to be marker

Table 2. Proportion and BMI for patients who had intersection points located at different positions of I' and B' for each landmark

		I'- & B'+		I'+ & B'+		I'- & B'-	
		Male	Female	Male	Female	Male	Female
SBPT'	%	93.86%	80.68%	1.75%	4.55%	4.38%	14.77%
	BMI	23.16 ± 2.30	19.88 ± 2.53	23.07 ± 3.87	20.91 ± 2.98	23.11 ± 2.15	20.24 ± 2.48
C'	%	92.11%	75.00%	1.75%	6.82%	6.14%	18.18%
	BMI	23.15 ± 2.30	19.84 ± 2.66	23.07 ± 3.87	21.01 ± 2.92	23.02 ± 2.56	20.35 ± 2.36
IBFH'	%	60.53%	50.00%	0	0	39.47%	50.00%
	BMI	22.97 ± 2.45	19.82 ± 2.50	0	0	23.31 ± 2.55	19.92 ± 2.50
SC	%	45.61%	38.64%	1.75%	0	52.63%	61.36%
	BMI	22.89 ± 2.57	20.03 ± 2.28	22.35 ± 4.02	0	23.09 ± 2.64	19.79 ± 2.98

BMI, (body mass index) were shown as mean ± standard deviation (SD). SBPT, superior border of pubic tubercle; PT, pubic tubercle; point B, femoral artery bifurcation; SC, inguinal skin crease; ASIS, anterior superior iliac spine; point C, the center of femoral head; IBFH, inferior border of femoral head; IEA, inferior epigastric artery; I', a straight line parallel to the connecting line of ASIS and SBPT through the lowest point of IEA loop; the horizontal lines drawn through point B, point C, SBPT and IBFH were labeled as B' and C', SBPT' and IBFH'.

lines, the intersection point was far from I' and B' by equal distance [DPI': -10.95 ± 0.374 cm, DPB': 14.30 ± 0.959 cm (SBPT'); DC'I': -9.58 ± 0.440 cm, DC'B': 18.25 ± 0.957 cm (C')]. However, the other two intersection points of IBFH' and SC with the femoral artery were close to B' [DIBFH'B': -0.24 ± 0.922 cm (IBFH'); SCB': -1.34 ± 1.034 cm (SC)]. In addition, the intersection points of SBPT', C', IBFH', and SC were compared with I' and B', and SBPT' as a landmark was associated with higher ratio of intersection point distal to I' and proximal to B' when compared with other landmarks (men: 93.86% vs. 92.11% vs. 60.53% vs. 45.61%; women: 80.68% vs. 75.00% vs. 50.00% vs. 38.64%; **Table 2**). SBPT' and C' were considered to be landmarks for comparison of BMIs owing to the significantly higher ratios of intersection points distal to I' and proximal to B' in SBPT' and C' compared with IBFH' and SC. Female patients with the intersection points proximal to I' and B' had higher BMI than those with intersection points distal to I' and proximal to B' (SBPT': 20.91 ± 2.98 cm vs 19.88 ± 2.53 cm, P = 0.040; C': 21.01 ± 2.92 cm vs 19.84 ± 2.66 cm, P = 0.018).

The linear relationship between DSBP and DASSB

Besides, the relationship between DSBP and DASSB was also analyzed. A significant linear relationship were observed between DSBP and DASSB (y = 0.424x - 23.439), and the relationship was superior in men than that in women (y = 0.442x - 26.982 vs. y = 0.312x - 5.496).

Discussion

The CFA has become an ideal catheter entry point on which FAP is usually performed because of its characteristics such as large size, less likely to be affected by disease, and easy to press on the underlying femoral head. As reported, the ratio of local vessel complications was less than 1% in FAP [21, 22]. Such a low incidence may be directly attributed to the puncture point being located on the CFA; otherwise, the incidence will increase significantly [23, 24]. Corresponding to the puncture point distal to the femoral artery bifurcation, various vascular complications occurred, such as pseudoaneurysm and arteriovenous fistula [20, 25]. Therefore, the femoral artery bifurcation was defined as a "low stick". In addition, the puncture point proximal to the inguinal ligament (IL) could also lead to external iliac artery injury, such as intra-abdominal and retroperitoneal hemorrhage (RPH) [24, 26]; thus, IL was defined as a "high stick".

In order to determine the "low stick" and "high stick" during fluoroscopy, two aspects should be considered: determination before angiography is needed to reduce vascular complications, and determination after angiography is needed to compare puncture procedures. In fact, we could only achieve better pre-angiographic determination by collecting post-angiographic data, and then, summarizing the related relationships. Therefore, the focus was shifted to anatomical structures. Determination of a "low stick" seemed simple, but various mistakes often occurred. For example, the landmarks were usually marked using anteroposterior fluoroscopy, but the access location was analyzed in angulated views, which would distort the landmarks [27]. In this study, the problems may be solved by identifying the location of the femoral artery bifurcation. In contrast, which anatomical structure can be considered as a "high stick"? The lowest point of the IEA loop was suggested by many researchers, because the vascular access at or above the lowest point of the IEA loop may result in the puncture of the external iliac artery, which is associated with a 17-fold higher incidence of RPH [7, 28]. However, the lowest point of the IEA loop as the "high stick" still has some disadvantages. For example, 8% IEAs originatingfrom the CFA werebelow the level of IL by 1-1.2 cm through anatomical dissections [29]; determination of a "high stick" to guide the puncture and reduce vascular complications before the IEA was angiographically identified. In this study, SBPT', which served as the optimal landmark, was demonstrated to be able to overcome these disadvantages as follows: (1) the location of the SBPT in the anteroposterior projection could be clearly identified; (2) selection of SBPT' as a landmark had a higher ratio of I'- and B'+ intersection points compared to other landmarks (C', IBFH', and SC); (3) IL was an anatomicallycurved structure that joins with ASIS and PT and has an intersection point with the femoral artery proximal to SBPT', while SBPT' was just the tangent of this curve; (4) the average distance between SBPT' and C' was -5.71 ± 4.63 mm, which was consistent with the target idea zone of 5-14 mm; and (5) the SBPT could be palpated in patients with relatively low BMI without the help of fluoroscopy.

In this study, a large amount of data wascollected to summarize the related disciplines for FAP. To ensure the accuracy of these data, the locations of all related anatomical structures in the anteroposterior projection should be identified, and the measurement methods should be defined accurately. Since theangulated views would distort the landmarks [27], we insisted on identifying the anatomical structures in the anteroposterior projection. After labeling the location, the exact location in the anteroposterior projection was re-identified to accurately determine the anatomical radial lines. Notably, researchers demonstrated the rationality of selecting the lowest point of the IEA loop as the landmark of IL and suggested that the puncture point distal to the horizontal line should be served as the marker to ensure the puncture point was not beyond the IL [7, 28, 30]. If the lowest point of the IEA loop is the landmark forIL, the line I' parallel to DASSB should also be drawn to serve as the IL, because IL is oblique but never horizontal. Besides, a linear relationship was found between DSBP and DASSB in this study. Moreover, the regression coefficients of men were higher than those of women, indicating that the determination of the femoral artery by SBPT is easier in men.

As reported, patients with higher BMI were more likely to have the IEA originating beneath the center line of the femoral head, and both IL and PT would have a lower anatomical relation with reference to the femoral head [14]. In this study, female patients with I'+ and B'+ were found to have significantly higher BMI than those with I'- and B'+. However, the average BMI was significantly lower than that reported from previous research [14]. This phenomenon may be due to the patients with advanced malignant cancer in our investigation who had low BMI due to long-term weight loss. Further, BMI was the integrated and quantified reflection of various factors, including sex, race, pelvic shape, and laxity of IL. Therefore, we suspect that using BMI alone was insufficient to determine the variation of anatomical locations.

A suggested technique

In clinical practice, if the tip of the left index finger touched the SBPT (fluoroscopic guidance could be considered if the SBPT cannot be accurately touched) and the index finger was horizontally placed on the patient's skin when performing FAP; the finger's proximal interphalangeal joint was exactly where the femoral artery was located on the level of the SBPT. Additionally, a larger DASSB would leadto a more lateral femoral artery, while a smaller DASSB would leadto a more medial one, which might also be adjusted according to the femoral pulse. This method involved a simple location of the femoral artery on the level of the SBPT based on $y = 0.442x - 26.982$ (men) and $y = 0.312x - 5.496$ (women).

Limitations

In this study, the relationship of the puncture sites with the complication rates was not studied. In addition, high-risk factors related to cardiovascular interventions (e.g. BSA < 1.73 m^2, acute myocardial infarction, use of GP IIb/IIIainhibitors, renal failure, diabetes, and cardiogenic shock) were scarcely mentioned in patients with malignant cancer. Furthermore, predictors of vessel complication showed sex difference (women: BMI and vessel size; men: diabetes and site of arteriotomy) [31], suggesting that men were most benefited by our investigation. Interestingly, men were identified to have a higher I'- and B'+ ratio, and a more efficient rule for finding the femoral artery was observed compared to women with SBPT' as a landmark.

There is a certain rule forlocating the femoral artery on the SBPT horizontally, which exhibits significant safety and simplicity. It is ideal to perform a femoral artery puncture atthe level of the SBPT. The puncture point is distal to the femoral artery bifurcation, and an undesired puncture to theinguinal ligament can be easily avoided. Further, BMI might affect the location of the IEA loop in female patients.

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Disclosure of conflict of interest

None.

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