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การศึกษาตำแหน่งของการใช้บอลลูนอุดตันเส้นเลือดแดงใหญ่เพื่อห้ามเลือดในการกู้ชีวิตในคนไทย

ภาณุ ธีรตกุลพิศาล, ผาติ อังคสิทธิ์*, ปาริชาติ ตันมิตร, สุภัชชา ประเสริฐเจริญสุข, ไชยยุทธ ธนไพศาล, ณรงชัย ว่องกลกิจศิลป์

ภาควิชาศัลยศาสตร์ คณะแพทยศาสตร์ มหาวิทยาลัยขอนแก่น

Position of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) in Thai People

Panu Teeratakulpisarn, Phati Angkasith*, Parichat Tanmit, Supatcha Prasertcharoensuk, Chaiyut Thanapaisal, Narongchai Wongkonkitsin,

Department of Surgery, Faculty of Medicine, Khon Kaen University, THAILAND

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หลักการและวัตถุประสงค์: สาเหตุของการเสียชีวิตจากอุบัติเหตุส่วนใหญ่เกิดจากภาวะเลือดออกในช่องท้อง ในสถานการณ์ปัจจุบัน การใช้บอลลูนอุดตันเส้นเลือดแดงใหญ่เพื่อห้ามเลือดในการกู้ชีวิตมีบทบาทในการห้ามเลือดในช่องท้องและอุ้งเชิงกราน แต่การทำหัตถการนี้จำเป็นต้องใช้เครื่องมือเพื่อยืนยันตำแหน่งที่เหมาะสมของอุปกรณ์ เช่น เครื่องส่องภาพรังสี แต่โรงพยาบาลส่วนใหญ่ในประเทศไทยไม่มีเครื่องมือนี้ที่ห้องฉุกเฉิน จึงเป็นที่มาของการศึกษานี้ เพื่อศึกษาตำแหน่งที่เหมาะสมในการใส่บอลลูนเปรียบเทียบกับอวัยวะภายนอกของร่างกาย

วิธีการศึกษา: ศึกษาจากร่างอาจารย์ใหญ่ โดยศึกษาเปรียบเทียบระยะภายนอก (คอหอย ลิ้นปี่ และสะดือ) และระยะทางภายในหลอดเลือด (หลอดเลือดแดง Subclavian, หลอดเลือดแดง celiac, หลอดเลือดไตซ้าย และจุดแยกของเส้นเลือดแดงใหญ่) กับบริเวณที่แทงเข็มทำหัตถการ (ขาหนีบ)

ผลการศึกษา: จากร่างอาจารย์ใหญ่ 22 ร่าง พบว่า ค่าเฉลี่ยของระยะภายนอกจากขาหนีบขวาไปยังสะดือ ลิ้นปี่และคอหอย เท่ากับ 19.20, 32.26, 53.42 ซม. จากขาหนีบซ้าย เท่ากับ 19.25, 32.62, 53.65 ซม. ระยะทางภายในหลอดเลือดจากขาหนีบขวาไปยังจุดแยกของเส้นเลือดแดงใหญ่ หลอดเลือดไตซ้าย หลอดเลือดแดง celiac และ หลอดเลือดแดง Subclavian เป็น 21.37, 30.47, 33.95, 55.97 ซม. จากข้างซ้ายเป็น 20.69, 29.72, 32.87, 56.20 ซม. โดยมีระยะห่างของอวัยวะภายนอกกับความยาวภายในหลอดเลือดที่มีความสัมพันธ์กันอย่างมีนัยสำคัญทางสถิติ คือ ขาหนีบขวาถึงสะดือกับจุดแยกของเส้นเลือดแดงใหญ่ (p=0.0385) และขาหนีบขวาถึงคอหอยกับหลอดเลือดแดง subclavian (p=0.303)

สรุป: การใช้อวัยวะภายนอกในการประมาณความยาวการใช้บอลลูนอุดตันเส้นเลือดแดงใหญ่เพื่อห้ามเลือดในการกู้ชีวิต ร่วม

Background and Objective: Major cause of trauma death worldwide is from non-compressible torso hemorrhage. Currently, Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) plays role in control of intraabdominal bleeding. Therefore, it is necessary to use several methods to confirm the position of the balloon precisely, such as fluoroscopy. But most hospitals in Thailand do not support fluoroscopic machine in ER. This study aimed to determine the intravascular length for placement REBOA and compare to the appropriate locations of external landmarks of the body.

Method: Human cadaveric study, external anatomical (sternal notch, xyphoid process and umbilicus) and intravascular (left subclavian artery (LSA), celiac trunk (CT), lowest renal artery (LRA) and aortic bifurcation (AB)) landmarks from puncture sites. The landing zones were calculated with intravascular landmarks.

Results: Twenty-two cadavers were analyzed. Mean external landmarks from right groin to umbilicus, xyphoid, sternal notch were 19.20, 32.26, 53.42 cm. and from left groin were 19.25, 32.62, 53.65 cm. The mean intravascular distance from right puncture site to AB, LRA, CT, LSA were 21.37, 30.47, 33.95, 55.97 cm. and from left puncture site were 20.69, 29.72, 32.87, 56.20 cm. There are statistically significant of clinical correlations between external and intravascular length of right groin - umbilicus with right

*Corresponding author : Phati Angkasith, Department of Surgery, Faculty of Medicine, Khon Kaen University, THAILAND. E-mail: phati@kku.ac.th

กับการประเมินการตอบสนองของผู้บาดเจ็บนั้นสามารถทำได้ อย่างไรก็ตามการใช้อวัยวะภายนอกเป็นจุดอ้างอิงตำแหน่งเพียงอย่างเดียวนั้น ต้องทำการศึกษาต่อไป

คำสำคัญ: การตกเลือดในช่องท้อง, การช่วยชีวิต, การช็อก, การบาดเจ็บ

puncture site - AB (p=0.0385) and right groin - sternal notch with right puncture site - LSA root (p=0.303). **Conclusion:** The use of external anatomical landmarks to estimate length of REBOA in Zone-1 and Zone-3 with evaluate the clinical response is safe to perform the procedure.

Key words: REBOA, Abdominal hemorrhage, Resuscitation, Shock, Trauma

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Introduction

The main cause of fatalities among accidents worldwide is low blood pressure due to hemorrhage.[1] The major treatment for patients with accidents is hemostasis, treatment of coagulopathy, fluid and oxygen supply to maintain blood pressure and treatment of hypothermia. We collectively as the Damage Control Resuscitation.2 In case of sudden cardiac arrest from non-compressible torso hemorrhage, may be necessary to perform resuscitative thoracotomy with aortic cross clamp.[3] The benefits are[4];

1. Increase afterload to the heart and increase blood supply to the organs above the aortic occlusion level that are brain and heart.
2. Reduce hemorrhage under aortic occlusion level such as abdominal or pelvic bleeding.

Currently, Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) plays a role in the control of bleeding in the abdomen and pelvic cavity as adjunct to hemorrhagic shock, which results in satisfactory treatment.[5,6]

Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) is an alternative treatment for the patients who suffering from hemorrhagic shock. This procedure is considered in patients with severe / refractory hemodynamic shock with non-compressible torso hemorrhage or isolated pelvic fractured which may be required pelvic packing together, due to mainly venous hemorrhage7-10. The contraindication of this procedure may be considered in patients with suspected thoracic aortic injury, such as high level ribs fractures, widening mediastinum or massive hemothorax. The use of balloon may result in greater arterial injury.

The steps in the procedure are as follows[5].

1. Arterial access

Femoral arteries are the most common used with ultrasound-guided percutaneous technique.

2. Balloon selection and positioning

Use a soft balloon and has a diameter large enough to occlude the aorta. The position of the balloon, need to perform the procedure to find the position by ultrasound8 or under a fluoroscopy. The placement of the balloon is divided into 3 zones depends on the location of hemorrhage.

Zone 1 : Left Subclavian artery – Celiac trunk

Using in severe instability patients or no pulse is palpated. Suggestions for balloon alignment above Celiac trunk. (Supraceliac occlusion)

Zone 2 : “No-occlusion zone” Celiac trunk – Lowest renal artery

Cannot place the balloon in this zone due to intraabdominal organ ischemia may occurs.

Zone 3 : Lowest renal artery – Aortic bifurcation

Used in patients expecting pelvic cavity hemorrhage that cannot be stopped by manual compression. (Figure 1)

3. Confirmation of balloon position

To determine the position of the balloon in the aorta, can be done with;

1) With imaging; Fluoroscopy (the most accuracy), plain X-ray, ultrasonography.

2) Without imaging; External landmarks and clinical response.

4. Balloon inflation

Inflate the balloon with water-soluble contrast solution 30-60 ml. By confirmation with imaging or clinical response.

5. Balloon deflation

Deflate the balloon slowly, so that blood supply in lower parts of the body after surgery or procedure done to stop the bleeding.

6. Sheath removal

Close the femoral artery in the groin by pressing (pressure application) or stitches to close the wound. There are three methods of estimating the position of the balloon in Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) procedure[1]. Perform under Fluoroscopy to position the balloon in the aorta.5 Thus, this is the most accurate technique[2]. Using ultrasonography to position the balloon. However, there is a downside: low accuracy and other factors to help confirm the correct position of the balloon,8 such as clinical response or palpate the lower extremity pulse. 3. Using of external landmark to estimate the length relative to the patient's organs, such as sternal notch or xyphoid process. Which is not very precise and no information to confirming the accuracy of this estimate as much.11 Therefore, it is necessary to have a fluoroscopy machine to confirm the precise position. Because of major hospitals in the country that does not support Fluoroscopy machine in the emergency room or resuscitation room. Researchers are interested in studying the length of the artery in the groin from the puncture site to the occlusion site correlates with the external anatomical landmarks to help confirmation of the location of the balloon. It also increases the accuracy and swiftness in the treatment of patients.

Methods

A cadaver based descriptive study was performed in faculty of Medicine, Khon Kaen university. Fresh cadaveric tissue dissection was conducted from February 2018 to December 2018. All fresh non-embalmed human bodies were kept in refrigerator at -20o C until 30 minutes before study, after that they were allowed to warm in room temperature. Age, sex, weight, height and BMI were collected for each cadaver. Any cadaver with vascular abnormality was excluded.

From the sampling of 20 patients monitoring Compute Tomography of the Aorta (CTA) found that average length between puncture and Celiac trunk was 32.2±2.7 cm., and the average length between puncture site and left subclavian artery was 56.8±3.9 cm., which is quite different. Therefore, this study determined the mean deviation of 0.6 cm. and when the numbers are calculated in the formula. Therefore, sample size in the study had at least 39 positions, or at least 20 cadavers.

External landmarks were measured in length from common femoral artery puncture site to umbilicus, xyphoid process and jugular notch. The groin (common femoral artery) puncture site was defined as 2 cm. inferior to midpoint of pubic tubercle and anterior superior iliac spine. All measurements were performed directly on top of the skin.

For the intravascular length, left thoracotomy was done to expose left subclavian artery root. After that, laparotomy was performed to expose the aortic bifurcation, the lowest renal artery root and celiac trunk. A femoral cut-down was performed at puncture site of both groins. Arteriotomy was made at both common femoral arteries. A guide wire was inserted under direct visualization then was advanced to the aortic bifurcation, lowest renal artery root, celiac trunk and left subclavian artery root. All of the distance via guide wire were recorded.

All of the external landmarks, intravascular length related to the landing zones of REBOA were calculated and correlated. Continuous data were presented in mean and standard deviation, and comparison using student T-test. Categorized data were presented in percent and compared using Chi-square and Fisher-exact test. P-values less than 0.05 were considered significantly. Statistical analysis was performed using STATA software version 10.1 (College Station, Texas, USA).

The Ethic Committee of Khon Kaen University approved this study on October 19th, 2017 (reference HE601404)

Results

From the study, the total number of cadavers was 24. One of the cadaver was decayed, and another one was severe atherosclerosis which cannot be inserted guide wire and were excluded from the study. Leaving the cadavers that look perfect and can study of total of 22 bodies, composed of 13 (59.1%) males and 9 (40.9%) females. The demographic data are shown in Table 1

The results measured the distance between the puncture site and external landmarks of the body of

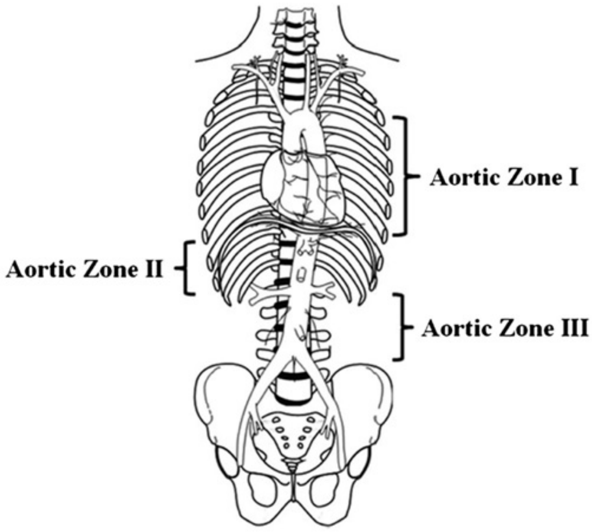

Figure 1 Aortic zones for balloon placements

the cadavers are in Table 2.

Measuring the length of the aorta from puncture site by accessing both common femoral arteries, and

Table 1 Demographic data

Cadavers	22		
Male	13	(59.1)	
Female	9	(40.9)	
Mean age (SD)	65.5	(10.97)	Year
Min - Max	44 – 86		Year
Mean height (SD)	159.68	(6.73)	cm.
Min - Max	150 - 171		cm.
Mean body weight (SD)	60.86	(7.52)	Kg.
Min - Max	47 - 72		Kg.
Mean BMI (SD)	23.96	(3.4)	kg./m^2

Table 2 Length between puncture site and external anatomical landmarks

	Mean	(SD)	Min	Max
Right groin				
Umbilicus	19.20	(2.90)	14.4	26
Xyphoid	32.26	(6.21)	19.5	46
Sternal notch	53.42	(4.53)	47.8	65
Left groin				
Umbilicus	19.25	(2.95)	13.7	25
Xyphoid	32.62	(5.87)	23	47
Sternal notch	53.65	(4.65)	47.8	64

Showing as Mean (SD), The units are in centimeters, N=22

Table 3 The length of the arteries from puncture site

	Mean	(SD)	Min	Max
Right common femoral artery				
Aortic bifurcation	21.37	(2.74)	16.8	26.8
Left renal artery root	30.47	(4.12)	22.2	42.8
Celiac trunk	33.95	(3.99)	28	45.6
Left subclavian artery root	55.97	(2.44)	50.3	59.2
Left common femoral artery				
Aortic bifurcation	20.69	(2.84)	16	26.4
Left renal artery root	29.72	(4.17)	23.3	42.6
Celiac trunk	32.87	(4.45)	24.5	45
Left subclavian artery root	56.20	(2.47)	53.4	62

Showing as Mean (SD), The units are in centimeters, N=22

insert the guide wire. Then performed laparotomy and left thoracotomy to measure various areas (aortic bifurcation, left renal artery and left subclavian artery root), the results are in Table 3.

The clinical correlation between length of external anatomical landmarks and actual length of the arteries are in Table 4. There are statistically significant correlations between the two lengths are right groin - umbilicus with right puncture site - aortic bifurcation (p=0.0385) and right groin - sternal notch with right puncture site - left subclavian a. root (p=0.303). The distribution of data is in Figure 2.

Discussion

Hemorrhage is the leading cause of death in multiple traumatic organ injuries.[1,12-14] The 80-percent of cases are potentially survivable.[11] At present, the REBOA has played a role in reducing mortality and preventing bleeding in patients with non-compressible bleeding in the abdomen and pelvis.[15]

Adam Stannard, et al[5] explains the estimation procedure to confirm the position of the balloon in 3 zones. Zone 1 is Left Subclavian artery to Celiac trunk. Zone 2 is Celiac trunk to the lowest Renal artery root. Zone 3 is the lowest Renal artery root to Aortic bifurcation. By inserting aortic balloon, it is often advisable to avoid insertion into zone-2 to avoid complications of Celiac trunk, Superior Mesenteric artery and Renal artery occlusion.

Confirmation of the position can be achieved by the use of imaging (fluoroscopy) or ultrasonography.[8]

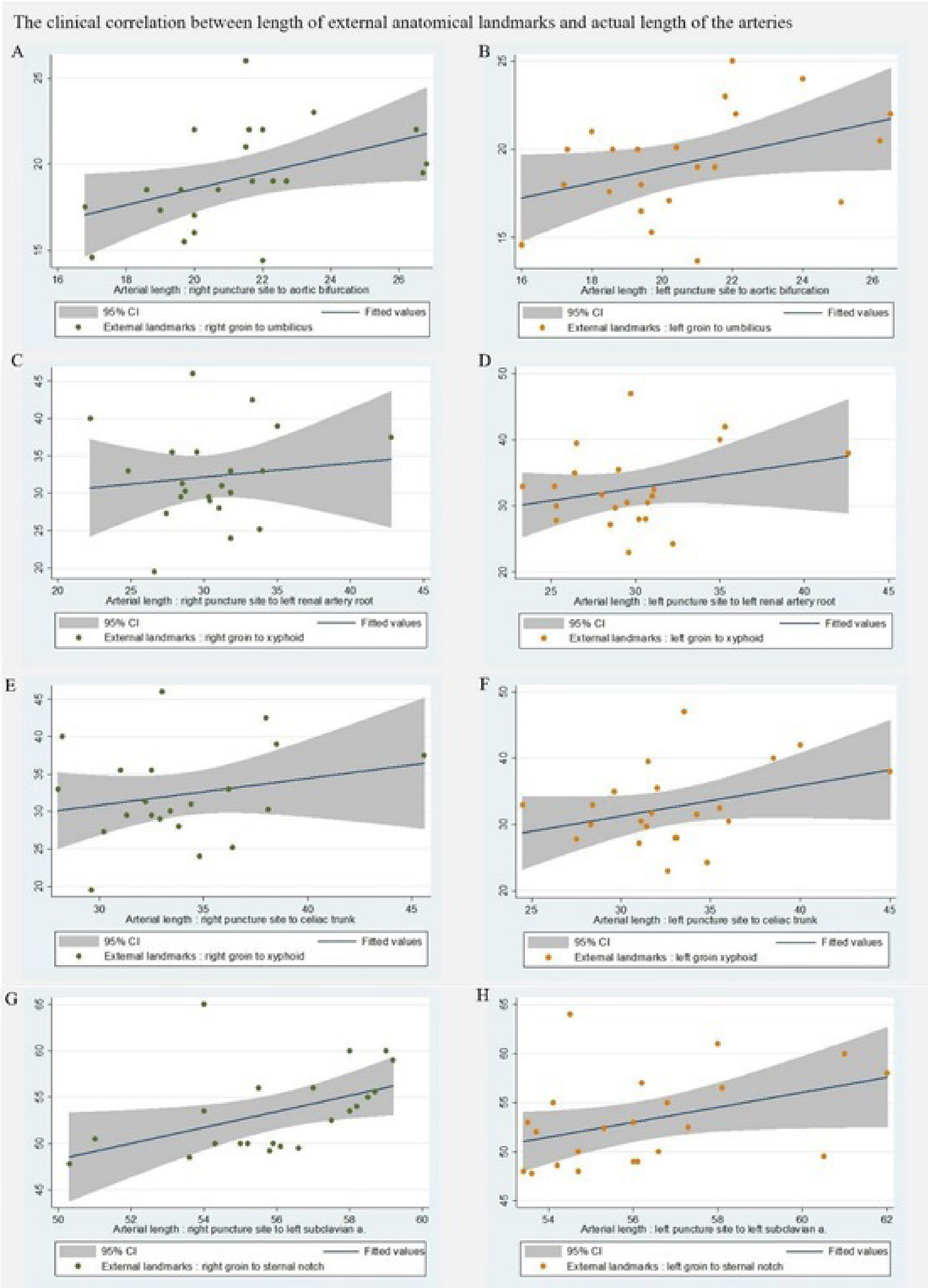

Figure 2 The distribution of data

Table 4 The clinical correlation between length of external anatomical landmarks and actual length of the arteries

	Clinical correlation (with internal length of vessel)	p-value	95% CI
Right puncture site			
Umbilicus (Aortic bifurcation)	0.44	0.0385	(0.027 - 0.729)
Xyphoid (Left renal artery root)	0.123	0.5852	(-0.315 – 0.518)
Xyphoid (Celiac trunk)	0.230	0.3029	(-0.212 – 0.594)
Sternal notch (Left subclavian artery)	0.462	0.0303	(0.050 – 0.074)
Left puncture site			
Umbilicus (Aortic bifurcation)	0.419	0.0583	(-0.015 – 0.709)
Xyphoid (Left renal artery root)	0.270	0.2237	(-0.171 – 0.621)
Xyphoid (Celiac trunk)	0.350	0.1107	(-0.084 – 0.672)
Sternal notch (Left subclavian artery)	0.404	0.0622	(0.021 – 0.705)

Showing as Mean (SD), The units are in centimeters, N=22

However, in Thailand, both confirmation procedures can be difficult, in order to not enough equipment in the emergency room. At present, the method to estimate the position of the balloon is comparison with the external anatomical landmarks. In other words, sternal notch represents left Subclavian artery root, xyphoid represent Celiac trunk and umbilicus represent Aortic bifurcation. In this study, the internal length of the arteries is compared with the external anatomical landmarks of the cadavers. The correlation of length from right puncture site to aortic bifurcation, left Subclavian artery root and from left puncture site to Aortic bifurcation have statistically significant. However the correlation of the length between both puncture sites and zone-2 (Celiac trunk, the lowest Renal artery root) has no statistically significant. This may be due to the distribution of information and the age group of the cadavers is mostly elderly.

From this study, show the insertion of balloon the balloon into Zone-1 and Zone-3, the use of external anatomical landmarks is represented. In Zone-1 the maximum length of the balloon should not exceed the sternal notch and in Zone-3 the level just above umbilicus should be safe to perform. But in the area near the xyphoid should be avoided, since there is not enough information.

Linnebur M and Inaba K, et al11 studied the body of the 10 cadavers, found that the length of the artery, compared to the external anatomical landmarks should be compatible but should have further studied.

This study was limited by the fact that the cadavers of the study had a relatively high age range, unlike the injured population this is usually the middle age. Moreover, vascular characteristics or atherosclerosis may also cause of adverse effect. The distribution of data is still very high, which may be required in more populations in the study. And recording of external anatomical landmarks may be necessary to add more variables such as mid-sternum, midpoint between the xyphoid and the umbilicus.

Conclusion

The use of external anatomical landmarks to estimate length of REBOA in zone-1 and zone-3 with evaluate the clinical response is safe to perform the procedure. However the use of only external anatomical landmarks alone should have more study by using this study to continue or further reference.

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References

1. ต้องพร วรรณธูป. REBOA : Resuscitative Endovascular Balloon Occlusion of the Aorta–Introduction for new life-saving maneuver in Trauma. Thai Journal of Trauma 2559; 35: 93-105.
2. Etienne G. Krug, Gyanendra K. Sharma, Rafael Lozano. The Global Burden of Injuries. Am J Public Health 2000; 90: 523-526.
3. Saito N, Matsumoto H, Yagi T, Hara Y, Hayashida K, Motomura T, et al. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. J Trauma Acute Care Surg 2014; 78: 897-904.
4. Morrison JJ, Galgon RE, Jansen JO, Cannon JW, Rasmussen TE, Eliason JL. A systematic review of the use of resuscitative endovascular balloon occlusion of the aorta in the management of hemorrhagic shock. J Trauma Acute Care Surg 2016; 80: 324-334.
5. Gupta BK, Khaneja SC, Flores L, Eastlick L, Longmore W, Shaftan GW. The role of intra-aortic balloon occlusion in penetrating abdominal trauma. J Trauma 1989; 29(6): 861–865.
6. Martinelli T, Thony F, Decléty P, Sengel C, Broux C, Tonetti J, et al. Intra-aortic balloon occlusion to salvage patients with life-threatening hemorrhagic shocks from pelvic fractures. J Trauma 2010; 68(4): 942-948.
7. Stannard A, Eliason JL, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (reboa) as an adjunct for hemorrhagic shock. J Trauma 2011; 71(6): 1869–1872.
8. Ogura T, Lefor AK, Nakamura M, Fujizuka K, Shiroto K, Nakano M. Ultrasound-Guided Resuscitative Endovascular Balloon Occlusion of the Aorta in the Resuscitation Area. J Emerg Med 2017; 52(5): 715–722.
9. Brenner ML, Moore LJ, DuBose JJ, Tyson GH, McNutt MK, Albarado RP, et al. A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation. J Trauma Acute Care Surg 2013; 75(3): 506–511.
10. Moore LJ, Brenner M, Kozar RA, Pasley J, Wade CE, Baraniuk MS, et al. Implementation of resuscitative endovascular balloon occlusion of the aorta as an alternative to resuscitative thoracotomy for noncompressible truncal hemorrhage: J Trauma Acute Care Surg 2015; 79(4): 523–532.
11. Linnebur M, Inaba K, Haltmeier T, Rasmussen TE, Smith J, Mendelsberg R, et al. Emergent non–image-guided resuscitative endovascular balloon occlusion of the aorta (REBOA) catheter placement: A cadaver-based study. J Trauma Acute Care Surg 2016; 81(3): 453–457.
12. Qasim ZA, Sikorski RA. Physiologic Considerations in Trauma Patients Undergoing Resuscitative Endovascular Balloon Occlusion of the Aorta. Anesth Anal 2017; 125(3): 891–894.
13. Aso S, Matsui H, Fushimi K, Yasunaga H. Resuscitative endovascular balloon occlusion of the aorta or resuscitative thoracotomy with aortic clamping for noncompressible torso hemorrhage: A retrospective nationwide study. J Trauma Acute Care Surg 2017 ; 82(5): 910–914.
14. Kisat M, Morrison JJ, Hashmi ZG, Efron DT, Rasmussen TE, Haider AH. Epidemiology and outcomes of non-compressible torso hemorrhage. J Surg Res 2013; 184(1): 414–421.
15. Manzano Nunez R, Naranjo MP, Foianini E, Ferrada P, Rincon E, García-Perdomo HA, et al. A meta-analysis of resuscitative endovascular balloon occlusion of the aorta (REBOA) or open aortic cross-clamping by resuscitative thoracotomy in non-compressible torso hemorrhage patients. World J Emerg Surg 2017; 12(1): 30.
16. Russo RM, Neff LP, Lamb CM, Cannon JW, Galante JM, Clement NF, et al. Partial Resuscitative Endovascular Balloon Occlusion of the Aorta in Swine Model of Hemorrhagic Shock. J Am Coll Surg 2016; 223(2): 359–368.
17. Scott DJ, Eliason JL, Villamaria C, Morrison JJ, Houston R, Spencer JR, et al. A novel fluoroscopy-free, resuscitative endovascular aortic balloon occlusion system in a model of hemorrhagic shock. JTrauma Acute Care Surg 2013; 75(1): 122–128.

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