International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 02, 2020
ISSN: 1475-7192

THE STABILITY OF INTERLOCKING STERNOTOMY TECHNIQUE ON JAVA GOAT STERNUM (*CAPRA AEGAGRUS HIRCUS*) IN VITRO BASED ON BIOMECHANICAL ANALYSIS

(Running Head: Interlocking Sternotomy Technique in *Capra Aegagrus Hircus* Sternum)

[1]Jayarasti Kusumanegara, [2*] Heroe Soebroto

ABSTRACT---Background: The stability of the sternum approximation is an important factor in preventing post-sternotomy complications in cardiac surgery caused by unstable sternum. The stability of the sternotomy can also be enhanced by the selection of good osteotomy techniques. The most common sternotomy technique is the median sternotomy.

Objective: To compare interlocking sternotomy technique with straight sternotomy technique on sternum stability of Javanese goat (Carpa aeragrus hircus) in vitro based on biomechanical analysis.

Methods: This in vitro study used 42 goat sternum bones. There were 21 sternums performed interlocking sternotomy and other 21 sternums were performed straight sternotomy. Sternotomy was conducted by using manual saws. Both halves of the sternum were fixed with a stitch of the figure of eight using a stainless-steel wire of 6 metric sizes. The yan biomechanical test consisted of transverse shear, longitudinal shear, and lateral distraction tests were performed on each group (7 sternums for each type of test) with loading from 100 Newtons to 400 Newtons of 0.2 Hertz.

Results: The average surface area of sternal fragments in interlocking sternotomy (19.6 cm^2) was greater than in straight sternotomy (18.2 cm^2). In the longitudinal shear and transversal shear tests, interlocking sternotomy was better than straight sternotomy and the difference was statistically significant ($p < 0.05$). However, in the lateral distraction test, there was no significant difference in both techniques ($p > 0.05$).

Keywords---Interlocking Sternotomy, Straight Sternotomy, Biomechanics, transversal shear, longitudinal shear, lateral distraction

---

[1][1]***Department of Thoracic, Cardiovascular and Vascular Surgery, Faculty of Medicine, Universitas Airlangga, Surabaya (60131), Indonesia***
[1]info@fk.unair.ac.id, (+6231) 5020251
[2]Department of Thoracic, Cardiovascular and Vascular Surgery, Faculty of Medicine, Universitas Airlangga, Surabaya (60131), Indonesia
unairsubroto@gmail.com, (+6231) 5020251
[*]Corresponding Author: Heroe Soebroto
DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020

I. INTRODUCTION

Sternotomy is the most access to cardiac and thoracic surgery. In the United States, more than 750,000 sternotomies are performed in one year for cardiac surgery. The use of sternotomy by surgeons since 1957 has become popular because the sternotomy provides an excellent mediastinal organ, relatively pain-free, and can heal well. Although it is widely used, the median sternotomy also has complications such as non-union, persistent pain, and infection with an incidence of 0.3-5% and has a mortality rate of 15-50% when there is mediastinitis. In Dr. Soetomo General Hospital Surabaya, cases of infection and sternal dehiscence caused by sternal instability are 1-4 cases each year. The percentage of sternal dehiscence in Dr. Soetomo General Hospital in 2016 was 2.26% [1].

Post-sternotomy complications have a negative impact on patients such as longer hospitalization, expenses, mobility and mortality. This further reinforces the importance of preventing complications and management in the event of such complications. Complications that can occur due to sternotomy can be prevented with sternum stability after a sternotomy. Inadequate sternal stability is generated by sternotomy and sternum fixation techniques that cause continuous movement of the unified sternum. Thus, stabilization of the sternum is a very important factor that plays a role in postoperative morbidity and mortality [2].

The sternotomy technique used is straight sternotomy whereas there are many different techniques used for median sternotomy closure. The biomechanical characteristics of each type of sternal closure are important in the reduction and stabilization of sternotomy [3]. Various sternum closure techniques are aimed at producing the most stable sternal fixation and require additional tools and materials. Stabilized sternum can also be maximized by the sternotomy technique used [4]. The interlocking technique of sternotomy appears to offer better stability with a wider surface area for bone healing than with other techniques. Therefore, this study compares the biomechanical characteristics of interlocking sternotomy technique compared with straight sternotomy technique on Javanese goat sternum.

II. METHODS

This research used in vitro clinical trial design on sternum of Javanese goat (Capra aegagrus hircus) which was carried out in Physics Science Laboratory of Faculty of Science and Technology Universitas Airlangga on July-August 2016. Inclusion criteria included Javanese goat sternum aged 1 - 1.5 years old who had 20-30 kg of Java goat weight. The exclusion criteria included transversal fracture on the sternum [5].

The research procedure included the patient selection stage, the sternal bone which fulfilled the inclusion criteria and the sternal bone was separated from the costa and the surrounding tissue was cleaned [6]. The research tool used one type of stainless steel wire material which was a stainless steel monofilament wire using the appropriate size for adult patients undergoing heart surgery, sternal saw which was manual triplex saw, sternal Closure Set, and servohydraulic autograph AG-10 TE to test the sternum biomechanically. Furthermore, the treatment stage included the sternum obtained from certified slaughterhouses was stored in a 0.9% NaCl physiological solution at 4° C until testing [7].

The test was performed by using hydraulic servohydraulic autograph AG-10 TE test machine. There were three types of tests performed on the sternum, namely transverse shear, longitudinal shear, and lateral distraction tests [8].

DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020

Data obtained from tensile tests between straight sternotomy techniques and interlocking sternotomy techniques were normally distributed based on Kolmogorov-Smirnov Test. The comparison between the two techniques was statistically analyzed using paired T-test [9].

III. RESULTS

From table 1, the number of samples in each sternotomy technique was 21 samples. The average area of contact between the sternal fragments of the interlocking sternotomy technique was 19.68 ± 2.2 cm2. The average area of contact between sternal fragments in straight sternotomy technique was 18.21 ± 2.27 cm2. Based on paired T-tests, there was no significant amount of contact area between the sternal fragments in both sternotomy techniques ($p > 0.05$). Based on Kolmogorov-Smirnov test, the data were normally distributed.

The group with a sternum model of a goat with interlocking sternotomy technique was tested by a lateral distraction, longitudinal shear, transverse shear with varying loads ranging from 100 N, 150 N, 200 N, 250 N, 300 N and 400 N respectively for 5 second (Table 2). From the result of tensile test to the interlocking sternotomy technique, it was found that at the load of 100 N up to 400 N with the lateral direction of distraction, longitudinal shear, and transversal shear, there was a shift in each load with a large shift.

The results of the longitudinal shear tensile test between straight sternotomy technique and the intelocking sternotomy technique showed a mean shift value (mm) towards the magnitude of the applied force load (Table 3). Statistically, based on the longitudinal shear test, there was a significant difference between straight sternotomy technique with interlocking sternotomy technique in almost all loading with $p < 0.05$ except on loading of 250 N. Average shift value (mm) in interlocking sternotomy technique was smaller than with a shift value (mm) in straight sternotomy technique.

IV. DISCUSSION

The result of statistic analysis on straight sternotomy technique toward 3 direction of the most distant and significant shift occurred in the lateral load distraction with 400 N load (3.63 ± 0.33 mm). In the interlocking technique of sternotomy toward 3-way load, the most distant shift was obtained at 400 N load at the lateral direction of distraction (3.67 ± 0.29 mm). In the lateral tensile distraction test on straight sternotomy technique, the shift was obtained between 0.37 ± 0.06 and 3.63 ± 0.33 mm while in interlocking sternotomy between 0.39 ± 0.05 mm and 3.67 ± 0.29 mm (at 100-400N load) [10].

In lateral distraction test, there was no significant difference between straight sternotomy technique with interlocking sternotomy technique on all loading with $p > 0.05$. This is due to the lateral distraction test; the resistance between the two halves of the sternum is almost the same between the two sternotomy techniques. The results of this study are consistent with studies in which the interlocking technique of sternotomy provides stability in anterior-posterior, cranio-caudal and lateral distraction although it is statistically significant only in the anterior-posterior and cranio-caudal directions [11]. In this study, the maximum loading resulting in a 2 mm shift was at 247 N on straight sternotomy and 253 N techniques in interlocking sternotomy technique. It is still within the range of force in normal respiration. Cough is a major problem associated with sternal stability. At the time of coughing, the resulting intrathoracic pressure can reach 300 mmHg or equivalent to 40 kPa (= 40000 N/m2)

DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020

Thus, the pressure gives a force to the sternum of F = P.A, where A is the area of the sternum. If the length of the sternum is estimated to be 20 cm and the sternal width is estimated to be 5 cm, the force applied to the sternum is F = 0.2x0.05x40000 = 400 N. The loading performed in this research is carried out for 5 seconds at each loading level. The mild coughing process, although having a force of 400 N, has a short duration of time of 0.2 second, so both of these sternotomy techniques are adequate to withstand a mild cough process, added with appropriate coughing techniques and the presence of thrust force from the patient's costae and chest wall [12].

Based on the sample characteristics, the average surface area between the sternal fragments in the interlocking sternotomy technique (19.68 ± 2.2 cm2) was greater than the mean surface area between the sternal fragments in straight sternotomy technique (18.21 ± 2.27 cm2) although there was no statistically significant difference in the area of contact between the two sternotomy techniques (p >0.05). When compared with studies that concluded that the area of contact between sternal fragments, the interlocking sternotomy technique (16.80 ± 0.78 cm^2) was greater than that of the straight sternotomy technique (10.40 ± 0.49 cm^2). The larger surface area of the contract of the sternal fragment will increase the sternum bone healing process.

In cranio-caudal (longitudinal) and anterior-posterior (transversal) movements, the interlocking technique of sternotomy is better and statistically significant compared with straight sternotomy [13]. However, in the lateral movement of distraction, these two techniques have no significant differences. This conclusion is consistent with studies conducted on sheep sternum animal in vitro in which interlocking sternotomy technique has superior stability compared with straight sternotomy technique [14]. In the interlocking sternotomy technique, respiratory function is better than in the straight sternotomy technique evaluated by peek expiratory flow rate (PEFR) in both groups of sternotomy techniques [15].

The superiority of the interlocking technique of sternotomy is also present in the sternum stroke examination. A study stated that the group with interlocking sternotomy technique has a mature amount of callus and the union of most bones. Groups with straighter sternotomy have only fibrous tissue and cartilage tissue. Thus, groups with interlocking sternotomy techniques have higher bone healing rates and fewer fibrous tissue [3].

In performing the interlocking sternotomy technique, the researcher should pay attention to the edges of the sternum because if the sternotomy wedge is too close to the edge of the sternum, it can cause transversal fractures. In interlocking sternotomy, the angle generated on the lazy-S slices is 150O in the coronal plane and perpendicular to each other on the axial plane. This interlocking sternotomy technique is similar to the technique used in previous research [12].

The sternal fixation using a figure-of-eight technique was performed as in sternum fixation used in heart surgery at Dr. Soetomo General Hospital Surabaya. This type of fixation is different from the sternal fixation of a similar previous study that used single suture for only 3 pieces; thus, it is expected that the fixation in this study can be stronger and stable. The number of twisting wires on the sternum is 3-4 times. This is in accordance with research that mentioned that as much as 3-4 times the twisting on wire has reached 80% - 88% maximum power without damaging the wire [13].

DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020

Withdrawal on the tensile test of each sternum sample must be mounted in the second sternum fragment; thus, it can be mounted on the test apparatus, potentially causing the indirect force load to be distributed to the fixation but through the plates and scruff mounted on the sternum. In addition, the gap displacement measurements was indirect on the sternal side, but on tensile testing machine that may produce different measurements [1].

V. CONCLUSION

Interlocking sternotomy technique has better stability than straight sternotomy technique based on biomechanical test. In the longitudinal shear biomechanical test, the interlocking sternotomy technique was better than straight sternotomy and was statistically significant ($p < 0.05$) in almost all loading. In transversal shear biomechanical tests, the interlocking sternotomy technique was better than straight sternotomy and was statistically significant ($p < 0.05$) at light load (100 N, 150 N, 200 N). In the lateral biomechanical distraction test, there was no significant difference between straight sternotomy technique and interlocking sternotomy ($p > 0.05$) on all loading.

ETHICAL CLEARANCE

This research process involves participants in the survey using a questionnaire that was accordant with the ethical research principle based on the regulation of research ethic committee. The present study was carried out in accordance with the research principles. This study implemented the basic principle ethics of respect, beneficence, nonmaleficence, and justice.

CONFLICT OF INTEREST

The author reports no conflict of interest of this work.

SOURCE OF FUNDING

This study is done with individual funding.

REFERENCES

[1] Kaul P. Sternal reconstruction after post-sternotomy mediastinitis. J Cardiothorac Surg. 2017;12(1):94.

[2] Bellomo RG, Barassi G, Colombo A, Pecoraro I, Irace G, Saggini R. Myofascial Manual Release In Cardiac Rehabilitation: Therapeutic Effects Post Sternotomy Surgery. Arch Physiother Glob Res. 2016;20(3).

[3] Riggs KW, Chin CW, Bryant R, Zafar F, Chin C, Schecter MG, et al. Heart-Lung Transplant via an Eighth-Time Sternotomy. World J Pediatr Congenit Hear Surg. 2019;2150135118815876.

[4] Nicol AJ, Navsaria P, Hommes M, Ball C, Edu S, Kahn D. Sternotomy or Drainage for a Hemopericardium After Penetrating Trauma: A Safe Procedure? Ann Surg. 2016;263(2):e32.

[5] Lastuti NDR, Rohman A, Handiyatno D, Chrismanto D, Desiandura K. Sequence analysis of the cytochrome c oxidase subunit 1 gene of Sarcoptes scabiei isolated from goats and rabbits in East Java, Indonesia. Vet world. 2019;12(7):959.

[6] Utomo DN, Hernugrahanto KD, Edward M, Widhiyanto L, Mahyudin F. Combination of bone marrow aspirate, cancellous bone allograft, and platelet-rich plasma as an alternative solution to critical-sized diaphyseal bone defect: A case series. Int J Surg Case Rep. 2019;58:178–85.

[7] Kusumastuti NP, Osaki M. Electric velocimetry and transthoracic echocardiography for non-invasive cardiac output monitoring in children after cardiac surgery. Crit Care. 2015;18(2):37.

[8] Bethenod F, Ellouze O, Berthoud V, Missaoui A, Cransac A, Aho S, et al. A single dose of tramadol in continuous wound analgesia with levobupivacaine does not reduce post-sternotomy pain: a randomized controlled trial. J Pain Res. 2019;12:2733.

[9] Miftahussurur M, Doohan D, Nusi IA, Adi P, Rezkitha YAA, Waskito LA, et al. Gastroesophageal reflux disease in an area with low Helicobacter pylori infection prevalence. PLoS One. 2018;13(11):e0205644.

[10] Sandhu HK, Tanaka A, Zaidi ST, Perlick A, Miller III CC, Safi HJ, et al. Impact of redo sternotomy on proximal aortic repair: Does previous aortic repair affect outcomes? J Thorac Cardiovasc Surg. 2019;

[11] Smith NJ, Miles B, Cain MT, Joyce LD, Pearson P, Joyce DL. Minimally invasive single -vessel left internal mammary to left anterior descending artery bypass grafting improves outcomes over conventional sternotomy: A single -institution retrospective cohort study. J Card

[12] Zeitani J. Sternotomy Techniques. 2018;

[13] Sepehri Shamloo A, Moeinipour A, Hoseinikhah H, Alizadeh L, Ansari MA, Tarjoman Porshokoh R. Wire-Box Fixation: An Alternative Technique for Sternal Closure After Median Sternotomy in Cardiac Surgery. Iran Hear J. 2018;19(4):13–7.

[14] Md Ali K. Physical function and sternal management following cardiac surgery via median sternotomy. 2017.

[15] Higgins JR, Kim NH, Kerr K, Fernandez T, Poch D, Madani M. A Comparison of Short Term Outcomes of Minimally Invasive versus Sternotomy Pulmonary Thromboendarterectomy. J Hear Lung Transplant. 2018;37(4):S25–6.

LIST OF TABLES

Table 1: Characteristics of Research Sample

Mean		n	SD	P
Interlocking	19.6786	21	2.20453	0.083
Straight	18.2090	21	2.26782	

Table 2: Results of Tensile Test on Straight Sternotomy and Interlocking Sternotomy

Load (Newton)	Lateral distraction (mm)	Longitudinal Shear (mm)	Transversal Shear (mm)
Straight Sternotomy			
100 N	0.37 ± 0.06	0.39 ± 0.07	0.40 ± 0.08

150 N	0.80 ± 0.10	0.61 ± 0.07	0.69 ± 0.16
200 N	1.31 ± 0.22	0.88 ± 0.10	0.96 ± 0.18
250 N	2.03 ± 0.24	1.47 ± 0.22	1.31 ± 0.31
300 N	2.75 ± 0.32	2.18 ± 0.20	1.98 ± 0.36
400 N	3.63 ± 0.33	3.09 ± 0.30	2.93 ± 0.35
Interlocking Sternotomy			
100 N	0.39 ± 0.05	0.21 ± 0.07	0.28 ± 0.09
150 N	0.82 ± 0.11	0.35 ± 0.12	0.48 ± 0.09
200 N	1.37 ± 0.08	0.58 ± 0.14	0.72 ± 0.14
250 N	1.95 ± 0.17	1.21 ± 0.30	1.03 ± 0.19
300 N	2.78 ± 0.30	1.76 ± 0.38	1.67 ± 0.15
400 N	3.67 ± 0.29	2.65 ± 0.32	2.62 ± 0.33

Table 3: The results of transversal shear, longitudinal shear and lateral distraction tensile tests on straight sternotomy and interlocking sternotomy technique

Load (Newton)	Straight Sternotomy (mm)	Interlocking Sternotomy (mm)	Harga p
Transverse shear tensile test			
100 N	[0.40 ± 0.08	0.28 ± 0.09	0.021
150 N	0.69 ± 0.16	0.48 ± 0.09	0.009
200 N	0.96 ± 0.18	0.72 ± 0.14	0.018
250 N	1.31 ± 0.31	1.03 ± 0.19	0.064
300 N	1.98 ± 0.36	1.67 ± 0.15	0.059
400 N	2.93 ± 0.35	2.62 ± 0.33	0.122
Longitudinal shear tensile test			
100 N	0.39±0.07	0.21±0.07	0.001
150 N	0.61±0.07	0.35±0.12	0.001

DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020

200 N	0.88±0.10	0.58±0.14	0.001
250 N	1.47±0.22	1.21±0.30	0.088
300 N	2.18±0.20	1.76±0.38	0.025
400 N	3.09±0.30	2.65±0.32	0.022
Lateral distraction tensile test			
100 N	0.37±0.06	0.39±0.05	0.535
150 N	0.80±0.10	0.82±0.11	0.678
200 N	1.31±0.22	1.37±0.08	0.474
250 N	2.03±0.24	1.95±0.17	0.285
300 N	2.75±0.32	2.78±0.30	0.852
400 N	3.63±0.33	3.67±0.29	0.794

DOI: 10.37200/IJPR/V24I2/PR200726
Received: 05 Jan 2020 | Revised: 20 Jan 2020 | Accepted: 30 Jan 2020