

# Comparing the Outcomes of Two Surgical Procedures – Minimally Invasive Surgery (MIS) and Conventional Surgery (CVS) on the Treatment of Degenerative Mitral Valve Diseases –Reflection on Group Work and Collaboration with Victoria Blackpool Hospital Cardiothoracic Surgery Department

Michael Halim<sup>1\*</sup>, Mariam AlSayegh<sup>1</sup>, Chidinma Angela Umenne<sup>1</sup>, Priyanka Vadithya<sup>1</sup>, Swetha Vishnu Panicker<sup>1</sup>  
Kasali Abayomi Israel<sup>1</sup>, Alice Halim<sup>2</sup>

<sup>1</sup>University of Salford, MSc Biomedical Science, Greater Manchester, United Kingdom

<sup>2</sup>Zhongshan Hospital, Shanghai Medical College of Fudan University, Shanghai, China

Corresponding author: Michael Halim

**Abstract:-** Different surgical procedures apply varying principles and are conducted under certain circumstances. This research focused on the difference between two surgical procedures, that is, Minimally Invasive Surgery (MIS) and Conventional Surgery (CVS) on the treatment of degenerative mitral valve diseases. The mitral valve, also known as the bicuspid valve, is located between the left atrium and ventricle of the heart. When the functions of this valve are impaired, it results in mitral regurgitation and mitral valve stenosis. Minimally Invasive Surgery (MIS) refers to any surgical procedure that involves very small incisions rather than large openings. On the other hand, Conventional Surgery (CVS) refers to a surgical procedure that is specialized and involves large openings with the use of a scalpel. These two procedures are used to treat degenerative mitral valve diseases, and their outcomes are not the same in terms of effectiveness thus the main objective of this research.

The research process took off by seeking relevant data and academic literature on the same. Since the research involved a real client, who is currently working as a cardiothoracic surgeon in Victoria Blackpool Hospital and as a professor from the University of Salford, he was briefed on the research and all our intentions. Each member of the group also came up with a write-up on the literature review on cardiac function. Having all the background information about the two surgical procedures after an intense research for almost 3 months, we managed to convince our client to send us the medical data collected from his patients over a span of almost three decades – from 1990s to 2020. The data was shared among all members and then analysed using Microsoft Excel. The propensity matching score is more accurate in the analysis, nonetheless, it is much more

complicated compared to Microsoft Excel and the time limit could not allow us to perform it. Suffice to say, we hope to perform the propensity matching score on the patient data, under the supervision of a biostatistician, and obtain a much better and accurate result in the future.

From the analysis of data, it was concluded that minimally invasive operations are more ideal as compared to conventional surgeries in various circumstances. On the parameters we identified, that is, blood loss that leads to the need for transfusion, cardiogenic shock, multiorgan system failure, and the risk for death, the MIS proved to have more merits compared to CVS.

**Keywords:-** Minimally Invasive Surgery (MIS), Conventional Surgery (CVS), mitral valve, medical data, disease, degenerative, surgical procedures, medical data.

## I. INTRODUCTION

Carrying out a task with a group may be perceived to be challenging (Harrison and Rouse, 2014) but it is often interesting when there are good communication and understanding among the group members (Cohen and Lotan, 2014). I was set for a group project with a team of five members with a supervisor and the client. I was positive about this project for ‘two heads are better than one’ therefore with the group I anticipated in-depth research with a variety of ideas (Maguire and Delahunt, 2017). I thought I could be a wonderful experience on how the five of us were going to interact with concerted efforts for a common goal. The project was about comparing two surgical procedures that are applied in the treatment of the degenerative mitral valve disease. These operative methods for comparison were

the minimally invasive surgery (MIS) and the conventional surgery (CVS) which are crucial in the treatment of cardiovascular disease (Axtell et al., 2020). Our objectives were to examine the outcomes of the two procedures on patients from Blackpool hospital. Then, from the results, we were to compare the two procedures and draw our conclusions and show which of the two is more effective.

I was excited to be part of this project since it is an important field to explore. In this project we were working with real-life working experience, an actual client, I was enthusiastic about the whole exercise. Moran et al. (2013) note that cardiovascular diseases are responsible for 31% of deaths globally. This data is supported by the World Health Organization (WHO) statistics on mortalities resulting from cardiovascular diseases (Cardiovascular diseases (CVDs), 2020). So, besides gaining more knowledge on the topic I understood that our project was going to significantly contribute to the field of medicine which made me feel an important person for our society. Interestingly, I became the communication officer of the team. I felt so comfortable with this responsibility for I did have prior experience for the duties of a communication officer from work. My duty was to enhance communication between the group members and Dr. Bittar who is the Cardiovascular surgeon at Victoria Blackpool hospital. He has a vast hands-on experience in this field. I developed a longing desire to work with this man and was thrilled to be the link between the group and the doctor. My other role was to provide platforms for communication between the group and the supervisor, DR. Pika Mclavc. Also, it was my responsibility to schedule meetings and communication among group members. We understood the importance of clearly defining everyone's roles as Malekoff (2015) notes that without this critical phase of group work we could not succeed. The other member too assumed the roles of the project manager, chairperson, chief technical officer, and secretary role.

## II. PROJECT PRELIMINARIES

First things first, we needed to understand how to we were going to carry out the study. We already had tutorials to refer to for the direction of the project. With this prior knowledge, we could guide each other and consult the supervisor when only necessary. I discussed the details of the project with my group members via WhatsApp. It was an interesting thing for I felt relevant and that my views matter as well as those of my members Orr (2016) notes that this is the pleasure of working in groups. I believe the feeling was mutual considering how enthusiastic and lively they were during the discussions. I was impressed with the motivation and readiness that every group member portrayed and the extra mile everyone was ready to go to ensure we achieved our goals. So, we began with intensive research on the project to acquire more knowledge on the study for this is critical before conducting any study (Levy and Ellis, 2016). We desired to have recent relevant data so we sought academic resources published between 2000 and 2020. We searched for these articles on databases such as PubMed, CINHALL, EBSCOhost for they are very resources and provide the most comprehensive way for searches

(Michaleff et al., 2014). Everyone exhibited a high level of collaboration. My group members owned the project and at no time was anyone reminded or pushed to accomplish a task. Working with these characters was enjoyable. Later, we sought for academic literature on MIS and CVS in the university of Salford library and sorted them in terms of relevance. Then we contacted our client through the email and we acquainted with through introductions and outlining our intentions. We later planned for a skype meeting since face to face meeting was not possible for safety precautions as a result of the COVID-19 pandemic. Although he had a busy schedule, we managed to have a 15-minute conversation in which he offered professional insights on the project and provided the patient's data compiled in a Microsoft Excel sheet for analysis. Later, we had a 25-minute skype meeting in which we discussed how the data can be analyzed where he recommended the use of a propensity matching test.

## III. RESEARCH FINDINGS

Every member conducted a literature review and came up with a write-up. My responsibility was to read and edit their work, compile, and discuss them when we met. I enjoyed going through their work and I was able to acknowledge the immense efforts my team put into this project. I appreciate their work and cooperation for they heed the deadlines that we had set for ourselves. From the searches, we were able to gather extensive information on cardiac function. I further acknowledged the role of the heart valves; being crucial in the blood circulatory system as they sustain the normal functioning of body organs by supplying the required oxygen and taking away the toxic carbon (IV) oxide (Mohammadi and Fradet, 2017). These valves prevent the backflow of blood to maintain a unidirectional flow which is vital for maximum gaseous exchange (Hendry, Farley and McLafferty, 2012). The mitral valve, also known as the bicuspid valve is located between the left atrium and ventricle of the heart (Shen, Wang, Cao and Cai, 2017). When the functions of this valve are impaired it results in mitral regurgitation and mitral valve stenosis (Choi, Rim, Mun and Kim, 2014). With mitral valve stenosis, the valve narrows as a result of mucopolysaccharide accumulation, deficient fibro elasticity, collagen alteration as well as myxomatous infiltration (Cottignoli et al., 2015; Gasser et al., 2018; Tamburino et al., 2013) hindering sufficient blood flow from the left atrium to the left ventricle (Nishimura, Vahanian, Eleid and Mack, 2016). The narrowing of the valve will then lead to atrium enlargement due to the improved blood volume and pressure (Sullivan, 2020) causing mitral valve prolapse, mitral valve stenosis, floppy mitral valve, flail leaflet as well as a mitral leaflet (Pellerin et al. 2012). On the other hand, mitral regurgitation will occur when the valve does not tightly close after the blood has been pumped out of the left atrium into the ventricle causing backflow upon pumping from the ventricle (Cui et al., 2014; Pouletty and Nakostech, 2014). These are the degenerative diseases corrected by surgery, that is, the Conventional Surgery (CVS) and the Minimally Invasive Surgery (MIS), and these are the

procedures we were to compare and find out which is more effective.

With the background information on the disease, we now delved into understanding the surgical methods and how they have advanced with time. Again, the contributions of my team members were great, they were intensive in their research and comprehensive in their write-ups. The CVS is the earliest successful surgical repair of the mitral in 1923 (Cao et al., 2015; Cao et al., 2013; Dieberg et al., 2016). The MIS was later invented in the mid-1990s as an alternative to CVS to enhance recovery with minimized trauma (Ritwick et al., 2013; Thongtrangan, Le, Park and Kim, 2014; Walther, Failk and Mohr, 2016; Modi, Hassan and Chitwood Jr, 2018). Due to the late discovery of the MIS, less literature is available on it compared to CVS. The difference between the two is that the CVS is done “10 cm right parasternal incision to expose the aortic and the mitral valve” (Milhaljevic et al., 2014). On the other hand, the MIS is carried out “through a 4-8cm right thoracotomy with additional port access for instruments” (Cao, 2020).

From the literature review on the comparisons between the two surgical procedures, we found interesting data. Both methods have their pros and cons. MIS reaps benefits from its incorporation of advanced technology of using small tools for tiny incisions with powerful cameras for target organs or tissue for identification (Pennington et al., 2018). There are two types of MIS, the robotic surgery, which uses robotic technology during operations (McClure et., 2013). With this method, there is high precision in making incisions normally accompanied advantages of reduced infection risk, enhanced post-operation recovery and less trauma as well as a significant reduction in blood loss and hospital stays (Modi et al., 2019; Wang et al., 2018; Grossi et al., 2012; Woo et al., 2016). The other type of MIS is referred to as endoscopic because the surgeon accesses the internal organs using small incisions with the help of the endoscope (Cheng et al., 2014; Chitwood Jr, 2015; Casselman et al., 2013). With this method, the miniature surgical tools are ferried via the tube while the internal organs are being monitored (Liberati et al., 2019). He associated benefits of this method include less scarring and reducing danger for infection since the procedure is usually carried under sterile conditions (Goldstone et al., 2013; Mandal, Alwair, Nifong, and Chitwood Jr, 2013; Bush, Nifong, Alwair and Chitwood Jr, 2013).

The CVS entails the inspection of the affected tissues and organs and then removing them (Speziale et al., 2014) aseptically to control the spread of infections (Raarani et al., 2013) with anesthesia administration (Dogan et al., 2015). The surgeons then clamp the blood vessels inhibiting bleeding during the procedure (Ryan et al., 2012). The associated advantages include; enhanced efficiency as a result of good exposure of the operation site (Suri, Schaff, Meyer and Hargrove, 2019), it is affordable and common in the health facilities and it is appropriate for clients that have a history of surgery (Grossi et al., 2014). However, the procedure requires large incisions (de Vaumas et al., 2013;

Svensson et al., 2012) and the recovery process is often painful and takes long (Gaudiani et al., 2014).

Following that, we then began analyzing the data sent to us via email by our client. For data analysis, we always met and collaborated in analyzing while seeking guidance from our tutor. We had learned of ethical concerns associated with using patients' information, so we requested our client to provide the medical data without identifiable information with it. The data was exclusively shared between the group members and the supervisors. Data analysis was the most difficult phase for us in our research. Our client had asked us to analyze the data with a propensity matching score which we all were blank about. It was a bit of a hurdle for us because our major is biomedical science and not statistics. So, we were advised, by our client, to contact a statistician from the university which I did. Unfortunately, the one I got was an epidemiologist and was not familiar with the propensity matching score. Eventually, we decided to analyze the data using Microsoft Excel instead. Even with Microsoft Excel, it was very difficult for us because our overall statistics skills were inadequate to begin with. We sought the guidance of our academic supervisor, Dr Pika, on the same coupling with online studies, we ultimately managed to acquire the skills and finally analyzed the data. The process of analyzing the data was extremely time consuming, and it took us around 10 days, because a lot of trial and error was involved. Needless to say, this was a stressful experience. Nonetheless, the struggle every group member exhibited was a motivation among us.

Suffice to say, we should have sought online help from an expert in propensity matching scores instead, assuming that we are able to find a qualified one, probably with the help of our academic supervisor - Dr Pika or our module head – Andrew Clarke. The efforts could have been worth it because most of the literature about mitral valve degenerative surgeries are performed using propensity matching score. Therefore, we might obtain better results and write a more comprehensive discussion and evaluation. Alternatively, we could have taken the time to study propensity matching score and then implementing it. Unfortunately, our time was limited and the propensity matching score is very complicated.

Finally, we had our results and we able to make conclusions. We again met and put our minds together to discuss our findings compare them with the available data and then make conclusions. The extensive research from each member was vital at this time and we never let each other down. The contributions they made depicted their efforts. Based on the data and literature analysis we comfortably concluded that: minimally invasive operations are more ideal as compared to conventional surgeries in various circumstances. On the parameters we identified that is blood loss that leads to the need for transfusion, cardiogenic shock, multiorgan system failure, and eh risk for death, the MIS performed statistically better than the CVS. However, the two procedures are not mutually exclusive from one another for it is dependent on the patient's

conditions with a combination of various factors. Therefore, the CVS cannot be replaced by MIS but the MIS can be prioritized.

The final part was report writing. The exercise was tedious since we had to meet the conditions of our supervisor. Furthermore, there was inadequate data on MIS as a result of its lateness discovery. For me, it was very tasking since I had to receive the reports from the group members and edit them. Then submit them to the supervisor

who could guide on the corrections and polishing that is needed. I submitted three drafts before the final paper. Maybe if I had attended a professional report writing class this wouldn't have been a tiresome experience. But am delighted to have learned the report writing skills in the process. Below is a flow chart representation providing a summary of the project process (figure 1) and a summary of how to make future improvements to avoid the difficulties faced (figure 2).

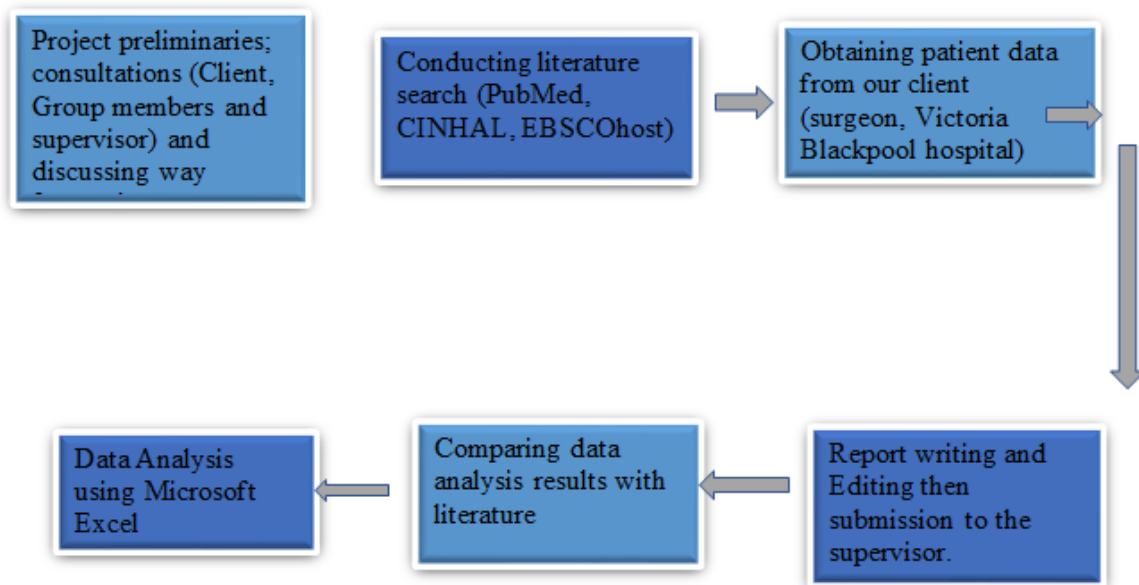


Fig 1:- summary of project progress

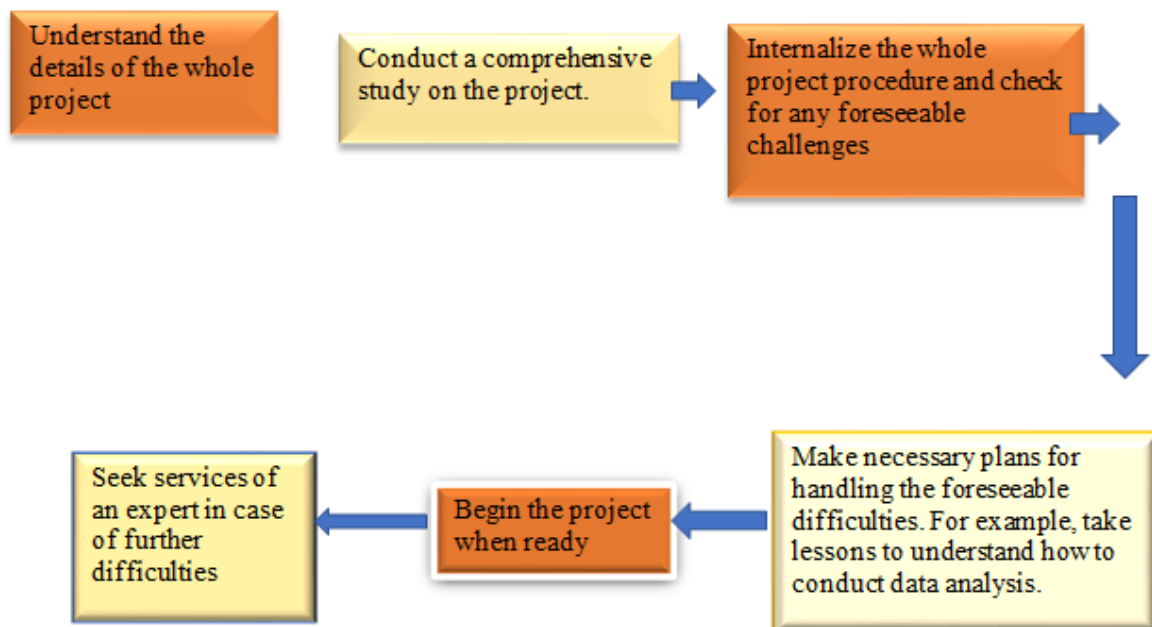


Fig 2:- Summary of future improvements

#### IV. SUMMARY

In summary, it was an easy task to complete the project but finally, we managed. The unprecedented COVID-19 pandemic took a hit on since we couldn't meet face to face with the supervisor and our client for some things that were not clear to us. But the other communication channels sufficed. I am contented with the overall efforts everyone put towards it and it made me realize the immense potential I have on report writings skills and data analysis.

#### REFERENCES

- [1]. Axtell, A.L., Moonsamy, P., Dal-Bianco, J.P., Passeri, J.J., Sundt, T.M. and Melnitchouk, S., 2020. Minimally invasive nonresectional mitral valve repair can be performed with excellent outcomes. *The Annals of Thoracic Surgery*, 109(2), pp.437-444.
- [2]. Bush, B., Nifong, L.W., Alwair, H. and Chitwood Jr, W.R., 2013. Robotic mitral valve surgery—current status and future directions. *Annals of cardiothoracic surgery*, 2(6), p.814.
- [3]. Cao, C., Gupta, S., Chandrakumar, D., Nienaber, T.A., Indraratna, P., Ang, S.C., Phan, K. and Yan, T.D., 2013. A meta-analysis of minimally invasive versus conventional mitral valve repair for patients with degenerative mitral disease. *Annals of cardiothoracic surgery*, 2(6), p.693.
- [4]. Cao, C., Wolfenden, H., Liou, K., Pathan, F., Gupta, S., Nienaber, T. A., Chandrakumar, D., Indraratna, P. and Yan, T.D., 2015. A meta-analysis of robotic vs. conventional mitral valve surgery. *Annals of cardiothoracic surgery*, 4(4), pp.305–314.
- [5]. Casselman, F.P., Van Slycke, S., Wellens, F., De Geest, R., Degrieck, I., Van Praet, F., Vermeulen, Y. and Vanermen, H., 2013. Mitral valve surgery can now routinely be performed endoscopically. *Circulation*, 108(10\_suppl\_1), pp.II-48.
- [6]. Cheng, D.C., Martin, J., Lal, A., Diegeler, A., Folliguet, T.A., Nifong, L.W., Perier, P., Raanani, E., Smith, J.M., Seeburger, J. and Falk, V., 2014. Minimally Invasive versus Conventional Open Mitral Valve Surgery a Meta-Analysis and Systematic Review. *Innovations*, 6(2), pp.84-103.
- [7]. Chitwood Jr, W.R., 2015. Current status of endoscopic and robotic mitral valve surgery. *The Annals of thoracic surgery*, 79(6), pp.S2248-S2253.
- [8]. Choi, A., Rim, Y., Mun, J.S. and Kim, H., 2014. A novel finite element-based patient-specific mitral valve repair: virtual ring annuloplasty. *Bio-medical materials and engineering*, 24(1), pp.341-347.
- [9]. Cohen, E.G. and Lotan, R.A., 2014. *Designing groupwork: strategies for the heterogeneous classroom third edition*. Teachers College Press.
- [10]. Cottignoli, V., Cavarretta, E., Salvador, L., Valfré, C. and Maras, A., 2015. Morphological and chemical study of pathological deposits in human aortic and mitral valve stenosis: a biomineralogical contribution. *Pathology research international*, 2015.
- [11]. Cui, Y.C., Li, K., Tian, Y., Yuan, W.M., Peng, P., Yang, J.Z., Zhang, B.J., Zhang, H.D., Wu, A.L. and Tang, Y., 2014. A pig model of ischemic mitral regurgitation induced by mitral chordae tendinae rupture and implantation of an ameroid constrictor. *PloS one*, 9(12).
- [12]. de Vaumas, C., Philip, I., Daccache, G., Depoix, J.P., Lecharny, J.B., Enguerand, D. and Desmonts, J.M., 2013. Comparison of mini-thoracotomy and conventional sternotomy approaches for valve surgery. *Journal of cardiothoracic and vascular anesthesia*, 17(3), pp.325-328.
- [13]. Dieberg, G., Smart, N.A. and King, N., 2016. Minimally invasive cardiac surgery: a systematic review and meta-analysis. *International journal of cardiology*, 223, pp. 554.
- [14]. Dogan, S., Aybek, T., Risteski, P.S., Detho, F., Rapp, A., Wimmer-Greinecker, G. and Moritz, A., 2015. Minimally invasive port access versus conventional mitral valve surgery: a prospective randomized study. *The Annals of thoracic surgery*, 79(2), pp.492-498.
- [15]. Gasser, S., Reichenspurner, H. and Girdauskas, E., 2018. Genomic analysis in patients with myxomatous mitral valve prolapse: current state of knowledge. *BMC cardiovascular disorders*, 18(1), p.41.
- [16]. Gaudiani, V.A., Grunkemeier, G.L., Castro, L.J., Fisher, A.L. and Wu, Y., 2014, January. Mitral valve operations through standard and smaller incisions. In *Heart Surg Forum* (Vol. 7, No. 4, pp. E337-E342).
- [17]. Goldstone, A.B., Atluri, P., Szeto, W.Y., Trubelja, A., Howard, J.L., MacArthur Jr, J.W., Newcomb, C., Donnelly, J.P., Kobrin, D.M., Sheridan, M.A. and Powers, C., 2013. Minimally invasive approach provides at least equivalent results for surgical correction of mitral regurgitation: a propensity-matched comparison. *The Journal of thoracic and cardiovascular surgery*, 145(3), pp.748-756.
- [18]. Grossi, E.A., Galloway, A.C., LaPietra, A., Ribakove, G.H., Ursomanno, P., Delianides, J., Culliford, A.T., Bizekis, C., Esposito, R.A., Baumann, F.G. and Kanchuger, M.S., 2012. Minimally invasive mitral valve surgery: a 6-year experience with 714 patients. *The Annals of thoracic surgery*, 74(3), pp.660-664.
- [19]. Grossi, E.A., LaPietra, A., Ribakove, G.H., Delianides, J., Esposito, R., Culliford, A.T., Derivaux, C.C., Applebaum, R.M., Kronzon, I., Steinberg, B.M. and Baumann, F.G., 2014. Minimally invasive versus sternotomy approaches for mitral reconstruction: comparison of intermediate-term results. *The Journal of thoracic and cardiovascular surgery*, 121(4), pp.708-713.
- [20]. Harrison, S.H. and Rouse, E.D., 2014. Let's dance! Elastic coordination in creative group work: A qualitative study of modern dancers. *Academy of Management Journal*, 57(5), pp.1256-1283.

- [21]. Levy, Y. and Ellis, T.J., 2016. A systems approach to conduct an effective literature review in support of information systems research. *Informing Science*, 9.
- [22]. Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P., Clarke, M., Devereaux, P.J., Kleijnen, J. and Moher, D., 2019. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of internal medicine*, 151(4), pp. W-65.
- [23]. Maguire, M. and Delahunt, B., 2017. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching and Learning in Higher Education*, 9(3).
- [24]. Malekoff, A., 2015. *Group work with adolescents: Principles and practice*. Guilford Publications.
- [25]. Mandal, K., Alwair, H., Nifong, W.L. and Chitwood Jr, W.R., 2013. Robotically assisted minimally invasive mitral valve surgery. *Journal of thoracic disease*, 5(Suppl 6), p.S694.
- [26]. McClure, R.S., Athanasopoulos, L.V., McGurk, S., Davidson, M.J., Couper, G.S. and Cohn, L.H., 2013. One thousand minimally invasive mitral valve operations: early outcomes, late outcomes, and echocardiographic follow-up. *The Journal of Thoracic and Cardiovascular Surgery*, 145(5), pp.1199-1206.
- [27]. Michaleff, Z.A., Costa, L.O., Moseley, A.M., Maher, C.G., Elkins, M.R., Herbert, R.D. and Sherrington, C., 2014. CENTRAL, PEDro, PubMed, and EMBASE are the most comprehensive databases indexing randomized controlled trials of physical therapy interventions. *Physical therapy*, 91(2), pp.190-197.
- [28]. Mihaljevic, T., Cohn, L.H., Unic, D., Aranki, S.F., Couper, G.S. and Byrne, J.G., 2014. One thousand minimally invasive valve operations: early and late results. *Annals of surgery*, 240(3), p.529.
- [29]. Modi, P., Hassan, A. and Chitwood Jr, W.R., 2018. Minimally invasive mitral valve surgery: a systematic review and meta-analysis. *European Journal of Cardio-Thoracic Surgery*, 34(5), pp.943-952.
- [30]. Modi, P., Rodriguez, E., Hargrove III, W.C., Hassan, A., Szeto, W.Y. and Chitwood Jr, W.R., 2019. Minimally invasive video-assisted mitral valve surgery: a 12-year, 2-center experience in 1178 patients. *The Journal of thoracic and cardiovascular surgery*, 137(6), pp.1481-1487.
- [31]. Mohammadi, H. and Fradet, G., 2017. Prosthetic aortic heart valves. *Cardiovas Syst*, 5, p.2.
- [32]. Moran, A., Forouzanfar, M., Sampson, U., Chugh, S., Feigin, V. and Mensah, G., 2013. The epidemiology of cardiovascular diseases in sub-Saharan Africa: the global burden of diseases, injuries and risk factors 2010 study. *Progress in cardiovascular diseases*, 56(3), pp.234-239.
- [33]. Nishimura, R.A., Vahanian, A., Eleid, M.F. and Mack, M.J., 2016. Mitral valve disease—current management and future challenges. *The Lancet*, 387(10025), pp.1324-1334.
- [34]. Orr, S., 2016. Collaborating or fighting for the marks? Students' experiences of group work assessment in the creative arts. *Assessment & Evaluation in Higher Education*, 35(3), pp.301-313.
- [35]. Pellerin, D., Brecker, S. and Veyrat, C., 2012. Degenerative mitral valve disease with emphasis on mitral valve prolapse. *Heart*, 88(suppl 4), iv20-iv28.
- [36]. Pennington, Z., Ahmed, A.K., Molina, C.A., Ehresman, J., Laufer, I. and Sciubba, D.M., 2018. Minimally invasive versus conventional spine surgery for vertebral metastases: a systematic review of the evidence. *Annals of translational medicine*, 6(6).
- [37]. Pouletty, P. and Nakostech SARM, 2014. *Mitral Valve Replacement System*. U.S. Patent Application 14/084, p.320.
- [38]. Raanani, E., Spiegelstein, D., Sternik, L., Preisman, S., Moshkovitz, Y., Smolinsky, A.K. and Shinfeld, A., 2013. Quality of mitral valve repair: median sternotomy versus port-access approach. *The Journal of thoracic and cardiovascular surgery*, 140(1), pp.86-90.
- [39]. Ritwick, B., Chaudhuri, K., Crouch, G., Edwards, J., Worthington, M. and Stuklis, R., 2013. Minimally Invasive Mitral Valve Procedures: The Current State. *Minimally Invasive Surgery*, 2013, pp.1-8.
- [40]. Ryan, W.H., Brinkman, W.T., Dewey, T.M., Mack, M.J., Prince, S.L. and Herbert, M.A., 2012. Mitral valve surgery: comparison of outcomes in matched sternotomy and port access groups. *The Journal of heart valve disease*, 19(1), pp.51-8.
- [41]. Shen, X., Wang, T., Cao, X. and Cai, L., 2017. The geometric model of the human mitral valve. *PLoS one*, 12(8).
- [42]. Speziale, G., Nasso, G., Esposito, G., Conte, M., Greco, E., Fattouch, K., Fiore, F., Del Giglio, M., Coppola, R. and Tavazzi, L., 2014. Results of mitral valve repair for Barlow disease (bileaflet prolapse) via right minithoracotomy versus conventional median sternotomy: a randomized trial. *The Journal of thoracic and cardiovascular surgery*, 142(1), pp.77-83.
- [43]. Sullivan, D. 2020. *Mitral Valve Stenosis: Causes, Symptoms, and Diagnosis*. [online] Healthline. Available at: <https://www.healthline.com/health/mitral-stenosis> [Accessed 5 May 5, 2020].
- [44]. Suri, R.M., Schaff, H.V., Meyer, S.R. and Hargrove III, W.C., 2019. Thoracoscopic versus open mitral valve repair: a propensity score analysis of early outcomes. *The Annals of thoracic surgery*, 88(4), pp.1185-1190.
- [45]. Svensson, L.G., Atik, F.A., Cosgrove, D.M., Blackstone, E.H., Rajeswaran, J., Krishnaswamy, G., Jin, U., Gillinov, A.M., Griffin, B., Navia, J.L. and Mihaljevic, T., 2012. Minimally invasive versus

- conventional mitral valve surgery: a propensity-matched comparison. *The Journal of Thoracic and Cardiovascular Surgery*, 139(4), pp.926-932.
- [46]. Thongtrangan, I., Le, H., Park, J. and Kim, D.H., 2014. Minimally invasive spinal surgery: a historical perspective. *Neurosurgical focus*, 16(1), pp.1-10.
- [47]. Walther, T., Falk, V. and Mohr, F.W., 2016. Minimally invasive surgery for valve disease. *Current problems in cardiology*, 31(6), pp.399-437.
- [48]. Wang, Q., Xue, X., Yang, J., Yang, Q., Wang, P., Wang, L., Zhang, P., Wang, S., Wang, J., Xu, J., Xiao, J. and Wang, Z., 2018. Right mini-thoracotomy approach reduces hospital stay and transfusion of mitral or tricuspid valve reoperation with non-inferior efficacy: evidence from propensity-matched study. *Journal of thoracic disease*, 10(8), pp.4789–4800.
- [49]. Who.int. 2020. *Cardiovascular Diseases (Cvds)*. [online] Available at: <[https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-\(cvds\)](https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds))> [Accessed 4 May 2020].
- [50]. Woo, Y.J., Rodriguez, E., Atluri, P. and Chitwood Jr, W.R., 2016, June. Minimally invasive, robotic, and off-pump mitral valve surgery. In *Seminars in Thoracic and Cardiovascular Surgery* (Vol. 18, No. 2, pp. 139-147). WB Saunders.