ISSN 1906-7984

Thai Journal of Neurological Surgery

วารสารประสาทศัลยศาสตร์ไทย

ปีที่ 15 ฉบับที่ 1 มกราคม - มีนาคม 2567
Vol. 15 No. 1 January - March 2024

วารสารประสาทศัลยศาสตร์ไทย
ปีที่ 15 ฉบับที่ 1 มกราคม - มีนาคม 2567

Thai Journal of Neurological Surgery
Vol. 15 No. 1 January - March 2024

เจ้าของ : ราชวิทยาลัยประสาทศัลยแพทย์แห่งประเทศไทย

สำนักงาน : อาคารเฉลิมพระบารมี ๕๐ ปี
เลขที่ 2 ซอยศูนย์วิจัย ถนนเพชรบุรีตัดใหม่ แขวงบางกะปิ
เขตห้วยขวาง กรุงเทพฯ ๑๐๓๑๐
โทรศัพท์ ๐๒-๗๑๘๑๙๙๖ โทรสาร ๐๒-๗๑๘๑๙๙๗

บรรณาธิการ : นายแพทย์ธีรพล วิทธิเวช

ออกแบบและพิมพ์ที่:

สำนักพิมพ์กรุงเทพเวชสาร
Bangkok Medical Publisher Ltd. Part.
3/3 สุขุมวิท 49 แขวงคลองตันเหนือ เขตวัฒนา กรุงเทพ 10110
โทรศัพท์ 0-2258-7954, 0-2662-4347, โทรสาร 02-258-7954
E-mail: bkkmed@gmail.com

วารสารประสาทศัลยศาสตร์ไทย
ปีที่ 2 ฉบับที่ 1 มกราคม - มีนาคม 2567
Thai Journal of Neurological Surgery
Vol. 2 No. 1 January - March 2024

คณะกรรมการบริหารราชวิทยาลัยประสาทศัลยแพทย์แห่งประเทศไทย

วารสารประสาทศัลยศาสตร์ไทย
ปีที่ 2 ฉบับที่ 1 มกราคม - มีนาคม 2567
Thai Journal of Neurological Surgery
Vol. 2 No. 1 January - March 2024

กองบรรณาธิการ

คำแนะนำในการส่งบทความ (Information for Authors)

วารสารประสาทศัลยศาสตร์ไทย ใช้ชื่อภาษาอังกฤษว่า "Thai Journal of Neurological Surgery" ใช้ชื่อย่อว่า "Thai J Neurol Surg" เป็นสื่อทางการของราชวิทยาลัยประสาทศัลยแพทย์แห่งประเทศไทย พิมพ์เผยแพร่แก่สมาชิกของราชวิทยาลัยฯ กำหนดออกทุก 3 เดือน โดยมีวัตถุประสงค์เพื่อ:

1. นำเสนอผลงานวิจัย ข้อเขียน บทความตลอดจนความคิดเห็นเชิงวิชาการทางประสาทศัลยศาสตร์และสาขาที่เกี่ยวข้อง
2. เป็นสื่อกลางใช้แลกเปลี่ยนความคิดเห็นต่างๆ ระหว่างสมาชิกของราชวิทยาลัยฯ
3. สนับสนุนกิจกรรมการศึกษาต่อเนื่องด้วยตนเองของสมาชิก

เพื่อให้บรรลุวัตถุประสงค์ดังกล่าว วารสารประสาทศัลยศาสตร์ไทย ยินดีรับบทความเป็นสื่อกลางระหว่างสมาชิกเพิ่มพูนความรู้ทางวิชาการแก่สมาชิกและวิชาการสาขาอื่นที่เกี่ยวข้อง บทความที่ส่งมาต้องไม่เคยพิมพ์เผยแพร่มาก่อน ข้อคิดเห็นในบทความ เนื้อหา และองค์ประกอบของเนื้อหาเป็นความรับผิดชอบของผู้เขียนบทความนั้น ราชวิทยาลัยประสาทศัลยแพทย์แห่งประเทศไทยไม่จำเป็นต้องเห็นพ้องด้วย และคณะบรรณาธิการขอสงวนสิทธิ์ในการตรวจทานแก้ไขและพิจารณาตีพิมพ์โดยมีหลักเกณฑ์ดังนี้

1. ประเภทบทความ

นิพนธ์ต้นฉบับ (Original articles)

เป็นรายงานผลงานวิจัย ค้นคว้า การเขียนบทความนิพนธ์ต้นฉบับให้ลำดับเนื้อหาดังต่อไปนี้

1. ชื่อเรื่อง (title), ผู้นิพนธ์ (author and co – authors), สถาบันที่ผู้นิพนธ์ปฏิบัติงาน (institute) และแหล่งทุนสนับสนุน (ถ้ามี)
2. บทคัดย่อ (abstract) ทั้งภาษาไทยและภาษาอังกฤษ
3. คำสำคัญ (key word) สำหรับจัดทำดัชนี ระบุไว้ใต้บทคัดย่อหรือ abstract
4. บทนำ (introduction)
5. วัสดุและวิธีการ (materials and methods)
6. ผลการศึกษา (results)
7. วิจารณ์ (discussions)
8. สรุป (conclusions)
9. เอกสารอ้างอิง (references)

บทความปริทัศน์ (review articles)

ควรเป็นบทความที่ให้ความรู้ใหม่ รวบรวมสิ่งตรวจพบใหม่ หรือเรื่องที่น่าสนใจที่สามารถนำไปประยุกต์ใช้ได้

หรือเป็นบทความวิเคราะห์โรค หรือ วิจารณ์สถานการณ์การเกิดโรค ประกอบด้วย

1. บทนำ (introduction)
2. วัตถุประสงค์ (objective)
3. เนื้อหาวิชา (content)
4. วิจารณ์ (discussions)
5. สรุป (conclusions)
6. เอกสารอ้างอิง (references)

รายงานผู้ป่วย (care report)

เขียนได้ 2 แบบ คือ รายงานอย่างละเอียด หรือสั้นๆ ประกอบด้วย บทนำ รายงานผู้ป่วยวิจารณ์อาการทางคลินิกผลตรวจทางห้องปฏิบัติการ เสนอ ข้อคิดเห็นอย่างมีขอบเขต สรุป บทคัดย่อ แนะนำให้มีภาษาไทย และภาษาอังกฤษ

บทความพิเศษ (special articles)

เขียนจากประสบการณ์ แสดงความคิดเห็น หรือจากการค้นคว้า

เทคนิคและเครื่องมืออุปกรณ์ (technique & instrumentation)

เพื่อเสนอเทคนิค หรืออุปกรณ์ใหม่ โดยจะต้องบอกข้อบ่งชี้ และผลการรักษาด้วย

จดหมายถึงบรรณาธิการ (letter to the editor)

เพื่อให้ความคิดเห็นเกี่ยวกับบทความที่ตีพิมพ์ไปแล้ว

2. เอกสารอ้างอิง (Reference)

การอ้างอิงใช้ตาม Vancouver Style หรือ Uniform Requirement for Manuscripts Submitted to Biomedical Journals, 5th edition ค.ศ. 1997 โดยใส่ตัวเลขยกระดับในเนื้อเรื่องตรงบริเวณที่อ้างอิง เรียงตามลำดับก่อนหลังการอ้างอิง แล้วจึงนำเอาเอกสารที่ถูกอ้างอิงมาเรียงตามลำดับการอ้างอิงท้ายบทความ บทความที่มีผู้นิพนธ์ไม่เกิน 6 คน ให้ใส่ชื่อผู้นิพนธ์ทั้งหมด ถ้าเกิน 6 คน ให้ใส่ 6 คน แล้วตามด้วย “et al.” หรือ “และคณะ”

การอ้างอิงเอกสาร

Broersen LHA, Biermasz NR, van Furth WR, de Vries F, Verstegen MJT, Dekkers OM, et al. Endoscopic vs. microscopic transsphenoidal surgery for Cushing’s disease: a systematic review and meta-analysis. Pituitary 2018;21(5):524-34.

การอ้างอิงวารสาร online

Sanders GD, Bayourni AM, Holodnity M, Owens DK. Cost-effectiveness of HIV screening in patients older than 55 year of age. Ann Intern Med [cited 2008 Oct 7]:148(2). Available from:http://www.annals.org/cgi/ reprint/148/12/889.pdf

การอ้างอิงจาก World Wide Web

National Institute for Health and Clinical Excellence. Head injury triage, assessment, investigation and early management of head injury in infants, children and adults. Clinical guideline June 2003. http://www.nice. org.uk guidance/CG4/?c = 91522 (accessed 23 November 2006).

การอ้างอิงหนังสือ หรือตำรา

ชื่อผู้เขียน. ชื่อหนังสือ. ครั้งที่พิมพ์ ชื่อเมือง (ใช้ชื่อเมืองชื่อเดียว): ชื่อโรงพิมพ์ ปี ค.ศ. ตัวอย่าง : Murray PR, Rosenthal KS, Kobayashi GS, Pfaller MA. Medical microbiology. 4th ed. St. Louis (MO): Mosby; 2002.

บทในหนังสือหรือตำรา

ชื่อผู้เขียน. ชื่อเรื่อง. ใน: ชื่อบรรณาธิการ. ชื่อหนังสือ. ครั้งที่พิมพ์. ชื่อเมือง. ชื่อโรงพิมพ์. ปี ค.ศ.: หน้าแรก-หน้าสุดท้าย

ตัวอย่าง: Meltzer PS, Kallioniemi A, Trent JM. Chromosome alterations in human solid tumors. In: Vogelstein B, Kinzler KW, editors. The genetic basis of human cancer. New York: McGraw-Hill; 2002. p. 93-113.

3. การพิมพ์และการส่งต้นฉบับ

- ให้ส่งต้นฉบับที่จะลงตีพิมพ์ โดยโปรแกรมที่ใช้พิมพ์ต้องเป็น Microsoft Word. Font Angsana New ขนาดตัวอักษร 16 พร้อมไฟล์ประกอบรูปภาพ และกราฟ รวมทั้งเอกสารรับรองจากคณะกรรมการจริยธรรมงานวิจัย (เฉพาะกรณีเป็นงานวิจัย) ไปยัง e-mail: journalrcnst@gmail.com
- การพิมพ์เนื้อเรื่องให้ใส่เลขหน้ากำกับทุกหน้าที่มุมขวาด้านบน

หน้าแรก หรือ title page เขียนเป็นภาษาไทยและอังกฤษ ประกอบด้วย

(1) ชื่อเรื่อง

(2) ชื่อ สกุลของผู้เขียน คุณวุฒิ โดยใช้ตัวอย่างของปริญญาหรือคุณวุฒิที่เป็นสากล (กรณีที่ผู้นิพธ์มีหลายคน ให้ระบุทุกคน)

(3) สถานที่ทำงาน

(4) ชื่อเรื่องอย่างย่อ หรือ running title (ความยาวไม่เกิน 40 ตัวอักษร)

4. การรับเรื่องตีพิมพ์

หากต้นฉบับที่เสนอมาได้รับการพิจารณาให้นำมาลงตีพิมพ์ ทางสำนักงานจะแจ้งให้เจ้าของบทความทราบพร้อมทั้งจัดส่งฉบับร่างให้ผู้เขียนตรวจทานและขอคืนตามกำหนดเวลา

5. สถานที่ติดต่อ

รศ.นพ.กิติพร ศรีอมรรัตนกุล
อาคารเฉลิมพระบารมี ๕๐ ปี
เลขที่ 2 ซอยศูนย์วิจัย ถนนเพชรบุรีตัดใหม่ แขวงบางกะปิ เขตห้วยขวาง กรุงเทพฯ 10310
โทรศัพท์ 02-7181 996 โทรสาร 02-7181 997
E-mail: kitiporn@nmu.ac.th

วารสารประสาทศัลยศาสตร์ไทย
ปีที่ 15 ฉบับที่ 1 มกราคม - มีนาคม 2567

Thai Journal of Neurological Surgery
Vol. 15 No. 1 January - March 2024

สารบัญ

Original Articles

Review Article

Thai J Neurol Surg 2024;15(1):1-5.

Original Article

Appropriate Concentration of Glycerin Solution for the Preservation of Fresh Cadaveric Vessels to be Used in Surgical Training: A Preliminary Study

Nawiya Kitkhuandee, M.D.
Natcha Kitkhuandee, M.D.
Sorawich Utsaha, M.D.
Department of Surgery, Khon Kaen University, Thailand

Abstract

Background: Training neurosurgeons on cadaveric blood vessels poses challenges in maintaining lifelike tissue properties for realistic surgical practice. This study aimed to determine the optimal glycerin concentration for preserving fresh cadaveric arteries while retaining flexibility, consistency, color, and fragility resembling living vessels.

Methods: Arterial vessels from two human placentas were harvested, trimmed to ≥5 cm lengths, and divided into five groups of three arteries each. The groups were embalmed in glycerin solutions of 3%, 10%, 20%, 40%, and 60% concentrations, respectively. After two years frozen at −20°C and two days at 5°C for slow thawing, the preserved arteries were evaluated by seven neurosurgeons. They performed cutting, suturing, and repair procedures, then rated satisfaction levels across tissue elasticity, handling, consistency, smell, color, fragility, realism, and overall quality.

Results: The arteries embalmed in 40% glycerin solution received the highest overall satisfaction ratings from surgeons.

Conclusions: A 40% glycerin solution proved most appropriate for preserving placental arteries to achieve lifelike characteristics for neurosurgical training purposes. Further studies using human cadaveric arteries and varying storage durations are warranted.

Key Words: Concentration glycerin; Preservation; Fresh cadaver; vessels

Corresponding author: **Nawiya Kitkhuandee, MD.**

บทคัดย่อ

หลักการและความเป็นมา: การฝึกทักษะการผ่าตัดของประสาทศัลยแพทย์ในหลอดเลือดของร่างอาจารย์ใหญ่ มีความท้าทายในการรักษาคุณสมบัติของเนื้อเยื่อให้เหมือนจริงสำหรับการฝึก การศึกษานี้จึงมีวัตถุประสงค์เพื่อหาความเหมาะสมของความเข้มข้นของกลีเซอรินสำหรับการนำมารักษาสภาพหลอดเลือดอาจารย์ใหญ่ให้รักษาความยืดหยุ่น ความสม่ำเสมอ สี และความเปราะบางที่คล้ายกับหลอดเลือดที่มีชีวิตจริง

วิธีการ: นำหลอดเลือดจากทารกมนุษย์สองชิ้น ตัดเอาหลอดเลือดแดงที่มีความยาวมากกว่าหรือเท่ากับ 5 เซนติเมตรรวม 15 เส้น และแบ่งเป็นกลุ่มห้ากลุ่ม โดยมีหลอดเลือดสามเส้นในแต่ละกลุ่ม ซึ่งนำไปเก็บไว้ในกลีเซอรินความเข้มข้น 3%, 10%, 20%, 40%, และ 60% ตามลำดับ หลังจากสองปีที่ถูกแช่แข็งที่ -20°C และนำออกมาลดอุณหภูมิที่ 5°Cเป็นเวลาสองวัน เพื่อให้เกิดการละลายอ่อนตัวอย่างค่อยเป็นค่อยไป และนำหลอดเลือดที่ถูกแช่ไปประเมินโดยประสาทศัลยแพทย์เจ็ดคน เพื่อประเมินในดำเนินการตัด เย็บ และซ่อมแซม แล้วให้คะแนนระดับความพึงพอใจในด้านความยืดหยุ่นของเนื้อเยื่อ, การจัดการ, ความสม่ำเสมอ, กลิ่น, สี, ความเปราะบาง, ความเป็นจริง และคุณภาพโดยรวม

ผลลัพธ์: หลอดเลือดที่ถูกแช่ในกลีเซอรินความเข้มข้น 40% ได้รับคะแนนความพึงพอใจรวมสูงสุดจากประสาทศัลยแพทย์

สรุป: สารละลายกลีเซอรินความเข้มข้น 40% มีความเหมาะสมที่สุดสำหรับการรักษาสภาพหลอดเลือดที่นำมาจากรก เพื่อให้ได้คุณลักษณะที่เหมือนจริงสำหรับการฝึกทักษะในการทำหัตถการทางประสาทศัลยกรรม การศึกษาเพิ่มเติมโดยใช้หลอดเลือดจากร่างอาจารย์ใหญ่และระยะเวลาการเก็บรักษาที่แตกต่างกันควรได้รับการศึกษาพัฒนาเพิ่มเติมในอนาคต

Introduction

In Thailand, most of them are Buddhists[1], where bodies are donated to be a cadaver for use. Residents and medical students receive a great deal of training in surgical practices. Nowadays, the training of neurosurgeons using the cadaver has greatly increased due to the increased safety of the treatment.[2] Neurosurgery, especially on arteries, is currently on the rise and is a necessary procedure especially for connecting blood vessels together in the world of cerebral aneurysms and chronic ischemic stroke such as Moyamoya's vessels disease.2 Preparing arteries realistically for use in surgical practice and suturing practice requires it to have the most realistic toughness and flexibility characteristics. In order for the preserved arteries from the cadaver to remain fresh, flexible, and realistic in size, it was necessary to keep the preserved arteries moisturized as close to reality as possible and to be able to preserve them without decay. Placing blood vessels in freezing temperatures causes the cells in the blood vessels to break down and lose their elasticity.[3]

Glycerin is a substance used to retain moisture, especially in skin cosmetics to reduce water loss from

the skin. It is usually a component of 60–70% of body lotions. Some studies have found that glycerin mixed with water at a ratio of approximately 2 to 1 can lower the freezing point of the solution as low as –40 degrees Celsius that stop the bacterial growth.[4] The glycerin solution is a solution that can maintain the moisture of the tissue and can make the temperature of the solution in the embalmed process have a very negative freezing point, so that the cells will not break down even if the temperature is negative, 5 which is the appropriate temperature, that will prevent microorganisms from growing.[4] The research studied to determine the appropriate concentration of glycerin solution for embalmed vascular tissue from cadaver for preservation in neurosurgery training.

Material and Method

The human placenta is the leftover specimen after birth. It is easily found in hospital as leftover specimen. This research uses two placenta tissues. The vessels were dissected to harvest the arterial vessels. The arterial from the placenta was trimmed and found 15 strands with a size of not less than 5 centimeters in length. The arteries were divided into 5 groups of 3 each and then embalmed in different solutions with glycerin concentrations of 3%, 10%, 20%, 40% and 60% respectively (Table 1). The arteries in the 5 bottoms of solution were then placed in a freezer at –20°C for two years, then placed at 5°C for 2 days to slowly increase the temperature from –20 Celsius to 5 Celsius. The results were given to seven neurosurgeons to test and practice arterial cutting and suturing and repairing and to rate their satisfaction in various aspects as follows: tissue elasticity, tissue handling, tissue consistency, smelling, color, tissue fragility, reality, overall satisfied score (Figure 1).

Table 1 Summary of Glycerin concentrations with satisfication of parameters

Parameter	Group 1	Group 2	Group 3	Group 4	Group 5
Glycerin concentration	2%	10%	20%	40%	60%
Tissue elasticity	2.3	3.8	4.5	5	5
Tissue handling	2.5	3.1	4.6	5	4.7
Tissue consistency	2	3.5	4.5	5	5
Smelling	3	3	5	5	5
Color	2	4	5	5	5
Tissue fragility	2.1	3.5	5	5	4.5
Reality	2.2	3.5	4.7	5	5
Others satisfied	2.3	3	4.7	5	5
Overall score	2.3	3.58	4.75	5	4.9

Note: Participant satisfactions (1=Not at all Satisfied, 2=Partly Satisfied, 3=Satisfied, 4=More than Satisfied, 5=Very Satisfied).

Figure 1 The image shows the process of collecting placental blood vessel samples, immersing them in solutions of varying concentrations, and evaluating of their usability by neurosurgeons.

Results

From a preliminary study of the satisfaction of the seven surgeons in those issue, it was found that they were most satisfied with the blood vessels embalmed in the 40% concentration glycerin solution (Table 1).

Discussion

In chemical science, when using 99% concentration glycerin solution, when the temperature drops to about 15 degrees Celsius, a semi-solid glycerin consistency is formed, which is not suitable for embalming, while 60% concentration glycerin solution in our research found as the same situation.[6] The results of this study demonstrate that a 40% glycerol solution is an appropriate concentration for embalmed of blood vessels for use in neurosurgery practice that can maintain the condition of blood vessels to remain flexible, consistent, and have an odor and color similar to the real condition. Including the fragility of the tissues at an appropriate level. This is consistent with previous research that found that glycerin solutions help preserve tissue without coagulation.

However, this study has limitations in using placental blood vessels as a surrogate for human cadaveric blood vessels. They may be different from blood vessels from actual human cadavers used in surgery. In addition, the 2-year sampling period may

cause some changes in the properties of the blood vessels. Therefore, in the next study consider using real blood vessels from cadaver and test shorter retention periods or longer as desired. This preserving of cadaveric blood vessels can increasing opportunities for residency training practice, result in higher skills and expertise.[7,10] Leads to better quality medical services.[8,9]

Conclusions

A 40% glycerin solution proved most appropriate for preserving placental arteries to achieve lifelike characteristics for neurosurgical training purposes. Further studies using human cadaveric arteries and varying storage durations are warranted.

References

1. Shotelersuk V, Limwongse C, Mahasirimongkol S. Genetics and genomics in Thailand: challenges and opportunities. Mol Genet Genomic Med. 2014;2(3):210-6. Available from: http://dx.doi.org/10.1002/mgg3.83
2. Lawton MT, Hamilton MG, Morcos JJ, Spetzler RF. Revascularization and aneurysm surgery: current techniques, indications, and outcome. Neurosurgery. 1996;38(1):83-94.
3. Shah TA, Mauriello CT, Hair PS, Sandhu A, Stolz MP, Bass WT, et al. Clinical hypothermia temperatures increase complement activation and cell destruction via the classical pathway. J Transl Med. 2014; 12:181.
4. Zhang B, Zhou J, Li X, Ye L, Jia D, Gan B, et al. Temperature affects substrate-associated bacterial composition during Ganoderma lucidum hyphal growth. Can J Microbiol. 2021;67(4):281-9.
5. Oldenhof H, Friedel K, Sieme H, Glasmacher B, Wolkers WF. Membrane permeability parameters for freezing of stallion sperm as determined by Fourier transform infrared spectroscopy. Cryobiology. 2010;61(1):115-22.
6. Petersen A, Schneider H, Rau G, Glasmacher B. A new approach for freezing of aqueous solutions under active control of the nucleation temperature. Cryobiology. 2006;53(2):248-57.
7. McNichols B, Spratt JR, George J, Rizzi S, Manning EW, Park K. Coronary Artery Bypass: Review of Surgical Techniques and Impact on Long-Term Revascularization Outcomes. Cardiol Ther. 2021;10(1):89-109.
8. Krähenbühl SM, Čvančara P, Stieglitz T, Bonvin R, Michetti M, Flahaut M, et al. Return of the cadaver: Key role of anatomic dissection for plastic surgery resident training. Medicine (Baltimore). 2017;96(29): E7528.
9. Cullinane DP, Barry DS. Dyad pedagogy in practical anatomy: A description of the implementation and student perceptions of an adaptive approach to cadaveric teaching. Anat Sci Educ. 2023;16(1):99-115.
10. McKechnie T, Springer JE, Doumouras AG, Schroeder T, Eskicioglu C, Reid S. Influence of undergraduate medical education exposure to cadaveric dissection on choice of surgical specialty: a national survey of Canadian surgical residents. Can J Surg. 2021;64(2): E183-E90.

วารสารประสาทศัลยศาสตร์ไทย
ปีที่ 15 ฉบับที่ 1 มกราคม - มีนาคม 2567

Thai J Neurol Surg 2024;15(1):6-23.

Research Article

Two-Years Comparative Clinical Outcome in the Shunt Treatment of Disproportionately Enlarged Subarachnoid Space Hydrocephalus (DESH) and Non-DESH Idiopathic Normal Pressure Hydrocephalus

Niiimron Nisahoh, MD[1]
Theerapol Witthiwej, MD[1]
Nerisa Thornsri, MD[2]

[1]*Division of Neurosurgery, Department of Surgery, Faculty of Medicine Siriraj Hospital*
[2]*Clinical Epidemiology Unit, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Abstract

Introduction: Idiopathic normal pressure hydrocephalus (iNPH) is known to be a treatable cause of disability and morbidity in elderly patients such as gait abnormality, cognitive decline, and urinary impairment. There are two types of iNPH, disproportionately enlargement subarachnoid space hydrocephalus (DESH) and non-DESH. This study aimed to compare, two-years outcome of treatment in both DESH and non-DESH.

Methods: We conducted a retrospective cohort study of iNPH patients who received surgical treatment between September 2014 and November 2016. Demographic data and baseline clinical were collected. The patient was classified into DESH and non-DESH iNPH groups. Outcomes after treatment such as idiopathic normal pressure hydrocephalus grading scale (iNPHGS), modified Rankin scale (mRS), bulbar symptoms, psychiatric symptoms, and adverse outcomes were analyzed during immediate post-operation, first visit, 4-6 months, 1 year, and 2 years after surgery. The positive outcome was defined as improvement in iNPHGS or mRS at such time.

Results: Patients with iNPH (n =106) were classified as DESH iNPH (n=72) and non-DESH (n = 34). There was a favorable improvement in both groups during the first visit (73.5% in non-DESH and 88.9% in DESH, p = 0.044), 4-6 months (72.7% in non-DESH and 79.4% in DESH group, p = 0.452), 1 year (65.9% in non-DESH group and 79.7% in DESH, p = 0.141) and 2 years (66.7% in non-DESH and 59.6% in DESH group, p = 0.54). There was no difference in outcome according to the type of surgery either ventriculoperitoneal (VP) or lumboperitoneal (LP) shunt at any time.

Conclusion: All patients with a diagnosis of iNPH should receive surgical treatment with or without DESH findings on radiographic imaging. There was a favorable positive outcome with minor shunt-related complications until at least 2 years after surgery. There were no differences between any shunting surgery at any time (either VP or LP shunt).

Keywords: idiopathic normal pressure hydrocephalus (iNPH), disproportionately enlargement of subarachnoid space with hydrocephalus (DESH), idiopathic normal pressure hydrocephalus grading scale (iNPHGS), modified Rankin scale (mRS), bulbar symptoms, psychiatric symptoms

Corresponding author: Niiimron Nisahoh, MD. Email: pminor158@gmail.com

บทคัดย่อ

บทนำ: โรคโพรงสมองคั่งน้ำชนิดความดันสมองปกติในผู้สูงอายุ (idiopathic normal pressure hydrocephalus: iNPH) มีผลทำให้เกิดความบกพร่องทางระบบประสาท ทำให้เกิดอัตราเสียชีวิตเพิ่มขึ้น ซึ่งเป็นโรคที่รักษาได้ด้วยการผ่าตัด โดย iNPH แบ่งได้เป็นสองประเภท ได้แก่ disproportionately enlargement subarachnoid space hydrocephalus (DESH) และ non-DESH การศึกษานี้เพื่อเปรียบเทียบผลการรักษาระยะยาวระหว่างกลุ่ม DESH และ non-DESH

วิธีการศึกษา: เป็นการศึกษาย้อนหลังในผู้ป่วย iNPH ที่ได้รับการผ่าตัด shunt surgery ระหว่างกันยายน 2014 ถึง พฤศจิกายน 2016 แบ่งผู้ป่วยเป็นกลุม DESH และ non-DESH โดยพิจารณาตามภาพรังสีระบบประสาท ผลลัพธ์ของการรักษาประเมินโดย idiopathic normal pressure hydrocephalus grading scale (iNPHGS), modified Rankin scale (mRS), อาการทาง bulbar และอาการทางจิตเวช ภาวะแทรกซ้อน ถูกประเมินที่ระยะหลังผ่าตัดทันที ระยะมาตรวจติดตามการรักษาครั้งแรก ที่ระยะ 4-6 เดือน ระยะ 1 และ 2 ปีหลังการผ่าตัดรักษา ผลลัพธ์ที่ดีจากการรักษาคือการเพิ่ม iNPHGS และ iNPH และmRS ในเวลาต่างๆ

ผลการศึกษา: ผู้ป่วย iNPH (n = 106) แบ่งเป็นกลุ่ม DESH (n = 72) และกลุ่ม non-DESH (n = 34) พบว่า favorable improvement ในทั้งสองกลุ่มในการติดตามครั้งแรก (73.5% ในกลุ่ม non-DESH และ 88.9% ในกลุ่ม DESH, p = 0.044) ที่ระยะ 4-6 เดือนหลังผ่าตัด (72.7% ในกลุ่ม non-DESH และ 79.4% ในกลุ่ม DESH, p = 0.452) ที่ระยะ 1 ปี (65.9% ในกลุ่ม non-DESH และ 79.7% ในกลุ่ม DESH, p = 0.141) ที่ระยะ 2 ปี (66.7% ในกลุ่ม non-DESH และ 59.6% ในกลุ่ม DESH, p = 0.54) โดยที่ไม่มีความแตกต่างระหว่างชนิดการผ่าตัด (ventriculoperitoneal [VP] หรือ lumboperitoneal [LP] shunt) ในระยะเวลาต่างๆ

สรุป: ในผู้ป่วย iNPH ทั้ง DESH และ non-DESH มีการตอบสนองต่อการผ่าตัดได้ดีจนถึงระยะ 2 ปีหลังการผ่าตัดรักษา โดยมีผลข้างเคียงเล็กน้อยจากการผ่าตัด โดยไม่มีความแตกต่างระหว่างชนิดของการผ่าตัดทั้งสองวิธี

Introduction

Nowadays, there were an increase in the elderly population in Thailand. In 2019, there were reported of 11 million elderly in Thailand accounting for 16% of the population.[1] According to an elderly person with dementia, some reported the prevalence of normal pressure hydrocephalus was about 0.9% of patients with dementia in the Geriatrics clinic.[2] Many experts proposed that idiopathic normal pressure hydrocephalus (iNPH) is one of the neurodegenerative diseases. Accordingly, the diagnosis of normal pressure hydrocephalus is increasing with advanced age. Patients with normal pressure hydrocephalus (NPH) had a clinical triad of Hakim defined as gait abnormality, cognitive impairment, and/or urinary disturbance with diagnostic brain imaging of brain demonstrated dilation of the ventricle (Evans' index[3] more than 0.3) according to NPH guidelines from American-European guideline[4], American Academy of Neurology Guideline[5] and Japanese iNPH guideline[6](JG). When clinical imaging of the patient was confirmed without other defined causes of hydrocephalus, hence the diagnosis of possible iNPH could be established. The spinal tap test also assured the diagnosis of probable iNPH.[7] According to American-European Guidelines (AEG) and Japanese Guideline (JG), there was some difference in the diagnosis of probable and possible iNPH.[8] In AEG[4], diagnosis of probable iNPH are symptoms

of gait/balance disturbance with at least one of two clinical symptoms i.e. a) cognitive impairment and b.) Urinary incontinence/urgency and including with ICP ≤ 20 cmH_2O and brain imaging of ventriculomegaly (Evans' index > 0.3) with at least one of these features i.e. a) Narrow callosal angle b) Enlargement of the temporal horns c) Periventricular signal changes. In contrast to JG6, diagnosis of possible iNPH with MRI support are any two of three symptoms in the clinical triad i.e. Gait disturbance, cognitive impairment and urinary incontinence and brain imaging of ventriculomegaly (Evan's index > 0.3) with a feature of narrowing of the sulci over the high convexity and/or Disproportionately enlarged subarachnoid space hydrocephalus (DESH). The diagnosis of definite iNPH was confirmed when the patient clinical improved after shunt surgery[9] composed of ventriculoperitoneal (VP) shunt, ventriculoatrial (VA) shunt, ventriculopleural shunt and lumboperitoneal (LP) shunt.[10] In addition to the Hakim triad, some patients suffered from other serious symptoms such as microaspiration[11], choking, hoarseness[12], mood disorders, depression or sleep disturbance (neuropsychiatric symptoms)[13] which can worsen patient condition into bed bound. If patients with probable iNPH left untreated, some[14] reported 5 years mortality rate as high as 87.5%. On imaging study, there was some feature which specific to idiopathic normal pressure hydrocephalus (iNPH), defined as Disproportional Enlargement of Subarachnoid space Hydrocephalus; DESH[15], according to Japanese guideline1',[16] which reported of a positive outcome in those patients with DESH appearance on imaging.[17] In the patient with no DESH appearance on imaging, defined as non-DESH or DESH-negative iNPH found to have a positive outcome after treatment.[17,18] Therefore, the objectives of this study were to examine whether there was a valuable outcome in the treatment of the patient with non-DESH iNPH group and to find out 2-years outcome after treatment in those groups.

Methods

Study design

The authors conducted a retrospective single-center cohort study of cerebrospinal fluid shunt (CSF) surgery for patients with iNPH in Siriraj hospital. All patients received either VP shunt or LP shunt surgery from September 2014 to November 2016 (26 months duration). Participants were grouped into DESH iNPH and non-DESH which were classified by neurosurgeons' perspective and neuroradiologists as shown in Figure 1. The primary measurement was the favorable outcome 1 year after surgery, which was either improvement of more than 1 point of the idiopathic Normal Pressure Hydrocephalus Grading Scale (iNPHGS)[10,19] or a modified Rankin Scale (mRS). The secondary measurements were favorable outcomes at the first visit (1-2 weeks), 4-6 months, and 2 years after surgery, which was defined above, improvement in neuropsychiatric (which include sleep disturbance) symptoms and bulbar symptoms (defined as either microaspiration, hoarseness of voice, choking, or speechless) at 4-6 months, 1 year and 2 years, respectively. The study protocol was approved by Siriraj Institutional Review Board.

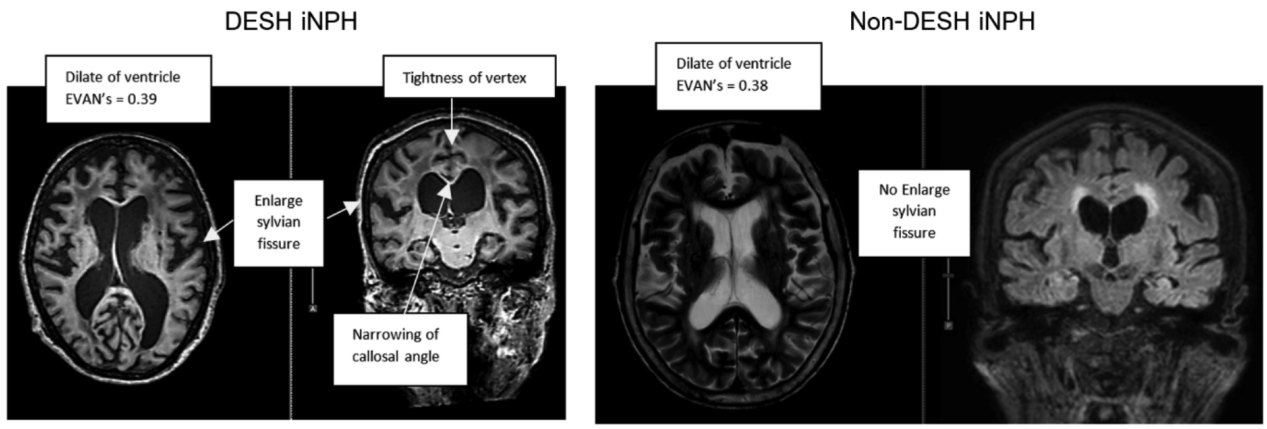


Figure 1 Imaging of DESH showing hydrocephalus with enlargement of subarachnoid space and tight vertex and narrowing of callosal angle and non-DESH iNPH showing hydrocephalus without sign of DESH (i.e. no tight vertex, mild dilate of subarachnoid space with no narrowing of callosal angle)

Study populations

All participants were patients with a diagnosis of suspected iNPH in Siriraj hospital between September 2014 and November 2016 who received CSF shunt surgery. The following inclusion criteria were 1) patient age > 60 years; 2) clinical triad of iNPH (abnormal gait, cognitive impairment, and urinary impairment) which is defined as iNPHGS; 3) Radiographic images of hydrocephalus, which defined as Evans' index > 0.3. Exclusion criteria were normal pressure hydrocephalus due to other defined causes and patients with no radiologic images documented from medical records.

Procedure and Outcome measurement

All patients who met all the above criteria were collected for statistical analysis. Participants were classified into two groups depending on radiographic appearance, based on neuroradiologists' and neurosurgeons' perspectives, comprised of DESH iNPH and non-DESH iNPH. All participants received surgery either VP shunt or LP shunt. For VP shunt, the implanted valves were either Codman Hakim® programmable valve with Siphonguard®, Medtronic programmable Strata II® or Medtronic fixed pressure valve®. Medtronic programmable NSC® valve, the only programmable LP shunt available in our institution, was used for LP shunt. The CSF shunt surgery was performed between September 2014 and November 2016 in our institution.

Preoperative data of participants were collected including patient characteristics (age and gender), comorbidities, preoperative iNPHGS[19], mRS, neuropsychiatric symptoms which are defined as any symptoms of mood disorders, depression, aggressiveness or sleep disturbance, and bulbar symptoms which defined as any symptoms of microaspiration, chocking or hoarseness of voice. The primary outcome measurement was the improvement of iNPHGS and/or mRS 1 year after surgery. Secondary outcomes were improvement of iNPHGS and/or mRS at 4-6 months, 1 year, and 2 years; improvement of neuro-

psychiatric and bulbar symptoms at 4–6 months, 1 year, and 2 years after surgery. Other outcomes were also collected; including adverse events at the first visit (usually 2–4 weeks), 4–6 months, 1 year, and 2 years after surgery (defined as medical complications and shunt-related complications). The positive response to surgery was defined as an improvement of 1 or more points in either iNPHGS or mRS at any evaluation point of the visit.

Statistical analysis

The categorical independent variables were presented as number or percentage, mean ±SD, or median (minimum, maximum) were carried out as appropriate distribution of data.

The association for univariate analysis, the categorical independent variables with DESH/non-DESH was assessed by the Chi-square test, and the significance of the continuous variable was assessed with a 2-sample independent *t*-test or Mann Whitney U test. A *p*-value of less than 0.05 was statistically significant. Statistical data were analyzed using SPSS version 18.

Results

Between September 2014 and November 2016 (26 months period), all data of diagnosed normal pressure hydrocephalus patients who received surgical treatment in Siriraj hospital were collected. One hundred thirty-five patients who underwent cerebrospinal fluid (CSF) shunt surgery were recorded in our institution. Anyway, twenty-four patients were reclassified as secondary NPH (sNPH) after intensely reviewing the complete data and 5 patients had no adequate record and/or imaging data. Accordingly, 29 out of 135 patients were excluded from this study, and 106 patients met the criteria of this study. Seventy-two out of 106 patients (67.9%) were classified as DESH iNPH whereas 34 out of 106 patients (32.1%) were non-DESH iNPH by definition. The ratio of DESH and non-DESH iNPH was 2:1 approximately. The CSF shunt surgery was performed using programmable ventriculoperitoneal (VP) shunt and programmable lumboperitoneal (LP) shunt depending on the neurosurgeon's preference. Codman® valve with or without Siphonguard or Medtronics Stata II® valve system was chosen for VP shunt in 62 patients (65.72%) but Medtronics NSC® valve which has had only one LP valve available in our institution was made in 44 patients (34.28%). The follow-up clinical and imaging data were reviewed at the first visit (usually 2–4 weeks), 4–6 months visit, 1 year, and finally 2 years visit. At 4–6 months follow-up period, 5 out of 106 patients (5.3%) lost to follow-up remained 92 patients. Nine out of 92 patients (8.28 %) were lost at 1 year follow-up period (VP shunt = 60, LP shunt =32). Finally, 17 out of 92 patients lost to follow up and 75 out of 106 patients (79.5%) remained in this study (VP shunt = 48, LP shunt = 27) at 2 years follow-up period. All number of patients was demonstrated in Figure 2.

Characteristics and clinical of patients at baseline

All demographic and underlying condition characteristics of patients are summarized in Table 1. Approximately two-thirds (67.9 %) of patients in this study were classified as DESH iNPH while around

one-third (32.1%) of patients were non-DESH iNPH. There was no statistical difference in age between DESH (77.8 ±7.5 years old) and non-DESH iNPH (78.8 ± 7.6 years old). Concerning gender, there was no statistical difference (p = 0.358) between DESH and non-DESH iNPH groups. According to the underlying diseases of the patients, we identified the comorbidity factors composed of cerebrovascular disease (CVA), Parkinson's disease (PD), Alzheimer's disease (AD)/dementia, benign prostatic hypertrophy (BPH), diabetes mellitus (DM), hypertension (HT), dyslipidemia (DLP), atrial fibrillation (AF), chronic kidney disease (CKD), ischemic heart disease (IHD) and others chronic diseases (e.g., hypothyroid, osteoarthritis, cirrhosis). Interestingly, there were only three conditions, PD, AD, and ischemic heart diseases, which seemed to be different between DESH and non-DESH groups but not statistically significant. Twenty-seven out of 106 patients (25.47%) had a history of Parkinson's disease. Concomitant with Parkinson's disease, 12 out of 34 patients (35.4%), presented in the non-DESH group while 15 out of 72 patients (20.8%) presented in the DESH iNPH group (p 0.111). For Alzheimer's disease, it seemed much more often in the non-DESH iNPH (23.5%) than DESH iNPH (9.7%) group but not statistically significant (p = 0.057). Lastly, a history of ischemic heart disease was frequently seen at 23.5% in non-DESH iNPH compared with 11.1% but not statistically significant (p 0.096) as well.

The mean baseline of clinical data of iNPH patients included the total and different three domains of iNPHGS, mRS, presented bulbar symptoms, and neuropsychiatric symptoms were demonstrated in Table 2. In comparison to the clinical characteristics of iNPH patients, there were no clinical statistically significant between DESH and non-DESH iNPH. The mean baseline total iNPHGS was 8.70 ± 1.98 in both iNPH groups as well as other domains of iNPHGS with a mean baseline gait score of 3.05 ± 0.72, mean baseline cognitive score of 2.81 ± 0.82, and mean baseline urinary score 2.82 ± 0.83. The quality of life determined by mean ± SD of the modified Rankin scale (mRS) was 3.77 ± 0.94. Interestingly, 79 out of 106 patients (74.5%) had bulbar symptoms which had a history of choking, hoarseness of voice, and microaspiration and 77 out of 106 patients (72.64%) had neuropsychiatric symptoms i.e. mood disorders, depression, aggressiveness or sleep disturbance but no difference between two groups of patients (p = 0.294 and p = 0.889, respectively).

Clinical outcomes after CSF shunt surgery

Adverse outcomes

The adverse events were defined into two groups: medical complications (e.g. hyponatremia, delirium, seizure, pneumonia, UTIs, sepsis, dizziness, psychotic symptoms) and shunt-related complications (i.e. shunt over-drainage with or without intracranial hemorrhage, shunt under drainage or malfunction, shunt malposition). There was 16.39% in overall adverse events which separated into 10.59% of medical complications and 5.8% in shunt-related complications. Most of the complications occurred after 4-6 months as shown in Figure 3 Adverse events after CSF shunting comparing non-DESH iNPH and DESH iNPH. According to shunt-related complications, there were no differences in both groups at

any time (Figure 3 Adverse events after CSF shunting comparing non-DESH iNPH and DESH iNPH. Details of the patient's shunt-related complications were described in detail (Table 3).

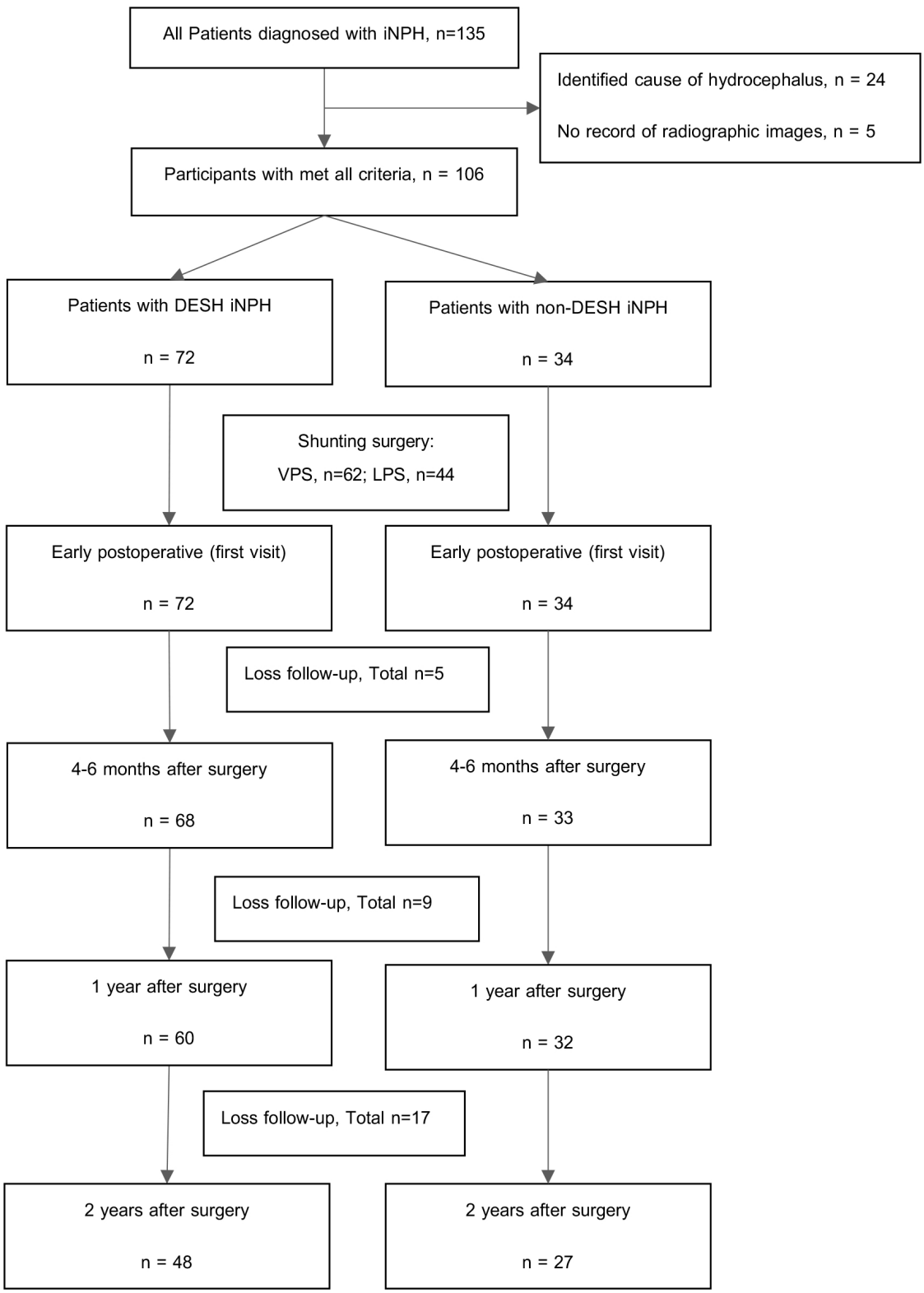


Figure 2 Flowchart showing number of patients from initial baseline to last outcome (2 years after surgery)

Table 1 Demographic data of study population

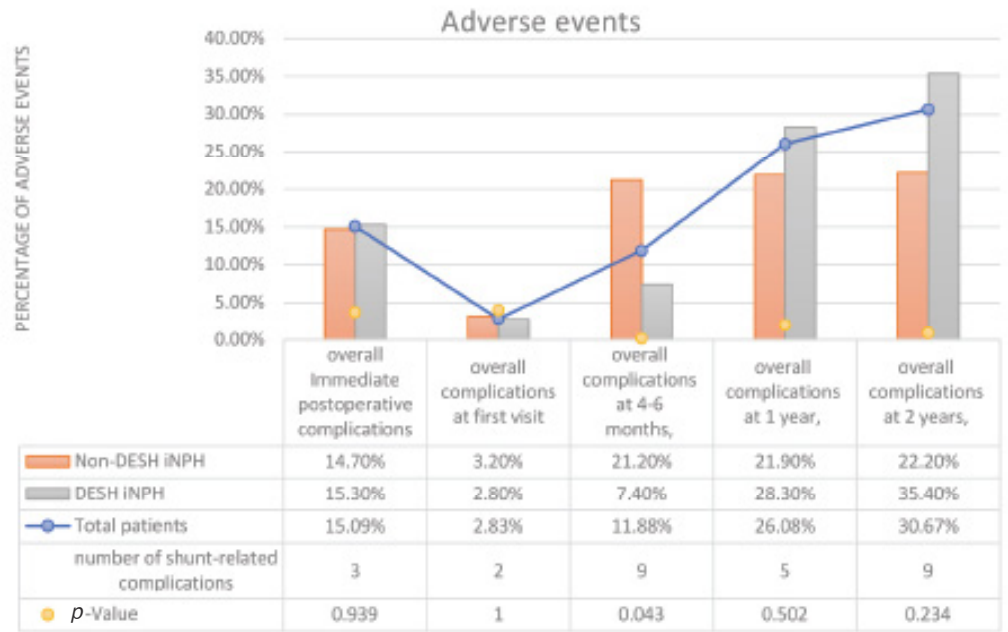
Parameter	Total No. of pts	Non-DESH iNPH	DESH iNPH	*p*-Value
Number of patients	106	34	72	
Age (years)		78.8±7.6	77.8±7.5	0.518
Gender: Male (%)	65	23 (67.6)	42 (58.3)	0.358
Female (%)	41	11 (32.4)	30 (41.7)	
Underlying conditions (%)				
- Cerebrovascular disease	26	7 (20.6)	19 (26.4)	0.517
- Parkinson's syndrome	27	12 (35.6)	15 (20.8)	0.111
- Alzheimer 's disease/Dementia	15	8 (23.5)	7 (9.7)	0.057
- Benign prostatic hypertrophy	19	7 (20.6)	12 (16.7)	0.623
- Diabetes Mellitus	34	9 (26.5)	25 (34.7)	0.396
- Hypertension	73	22 (64.7)	51 (70.8)	0.525
- Dyslipidemia	30	9 (26.5)	21 (29.2)	0.774
- Atrial fibrillation	5	2 (5.9)	3 (4.2)	0.655
- Chronic kidney disease	13	2 (5.9)	11 (15.3)	0.169
- Ischemic heart disease	16	8 (23.5)	8 (11.1)	0.096
Others (e.g. Hypothyroid, Osteoarthritis, cirrhosis)	22			

Table 2 Clinical characteristics (iNPHGS, mRS, bulbar symptoms, and psychiatric symptoms) of the study population comparing DESH iNPH group and non-DESH iNPH

Pre-preoperative status	Total (n=106)	Non-DESH iNPH (n=34)	DESH iNPH (n=72)	*p*-Value
iNPHGS, mean ± SD	8.70 ± 1.98	8.65 ± 1.98	8.72 ± 2.0	0.686
- Gait score	3.05 ± 0.72	2.88 ± 0.76	3.13 ± 0.69	
- Cognitive score	2.81 ± 0.82	2.82 ± 0.79	2.81 ± 0.83	
- Urinary score	2.82 ± 0.83	2.91 ± 0.75	2.78 ± 0.86	
mRS, mean ± SD	3.77 ± 0.94	3.74 ± 0.86	3.79 ± 0.97	0.597
No. of patients with bulbar symptoms (no)	79	26	53	0.294
No. of patients with neuropsychiatric symptoms (no)	77	25	52	0.889

Outcome at the first visit

Clinical outcome at the first visit, usually 2-4 weeks after surgery, was described as a subjective improvement by patients, relatives, or clinicians. There was a higher improvement in DESH iNPH (88.9%) than non-DESH iNPH (73.5%, $p = 0.04$) as shown in Tabe 4. Meanwhile, adverse outcomes (including shunt-related complications) least occurred during this time (Figure 3 Adverse events after CSF shunting comparing non-DESH iNPH and DESH iNPH).



	overall Immediate postoperative complications	overall complications at first visit	overall complications at 4-6 months,	overall complications at 1 year,	overall complications at 2 years,
Non-DESH iNPH	14.70%	3.20%	21.20%	21.90%	22.20%
DESH iNPH	15.30%	2.80%	7.40%	28.30%	35.40%
Total patients	15.09%	2.83%	11.88%	26.08%	30.67%
number of shunt-related complications	3	2	9	5	9
p-Value	0.939	1	0.043	0.502	0.234

Figure 3 Adverse events after CSF shunting comparing non-DESH iNPH and DESH iNPH

Results at 4-6 months after surgery

At 4 to 6 months after shunt surgery, the total number of patients was 101 out of 106. the mean ± SD of iNPHGS of 7.10 ± 2.78 which decreased than the mean ± SD of iNPHGS of 8.70 ± 1.98 in the preoperative period but had no statistic significant (p 0.850) between DESH and non-DESH iNPH as well as the other domain of iNPHGS which has had better than preoperative period. The quality of life of DESH and non-DESH iNPH was slightly improved with a mean ± SD of mRS (3.24 ± 1.13) compared to preoperative mRS (3.77 ± 0. 94).

Moreover, 50 out of 87 patients (57.47%) had improvement in bulbar symptoms which had a history of choking and microaspiration, and 43 out of 84 patients (51.19%) had improvement in neuropsychiatric symptoms but no difference between DESH and non-DESH iNPH patients (Table 5). Meanwhile, a higher incidence of adverse events occurred during 4-6 months (11.88%) with more frequent in non-DESH group (21.2%) compared to DESH group (7.4%) at 4-6 months (p = 0.043).

Table 3 Described patients with shunt-related complications

No.	age	underlying	imaging	pre-op INPHGS	pre-op mRS	type of surgery	complication	time after surgery	treatment	final outcome
1	89	HT, spinal stenosis, OA knee	non-DESH	9	4	VP shunt (Codmans with	Abdominal wall hematoma	immediate	Explore wound with clot removal	improve
2	82	DM, Alzheimer's disease, gout, IHD	non-DESH	9	4	VP shunt (Codmans with	Shunt malposition	first visit	-	not improve
3	86	HT, DLP	DESH	6	2	LP shunt	Abdominal pseudocyst	first visit	Revise LP shunt	improve
4	75	PD, old CVA, DLP	non-DESH	7	4	VP shunt (Codmans with siphonguard)	Shunt malposition	4-6 months	revise VP shunt	improve
5	76	DM, HT, CA prostate	non-DESH	7	2	LP shunt	shunt overdrainage with SDH	4-6 months	-	not improve
6	63	DM, HT, old CVA, DLP, IHD, OA knee	DESH	9	4	VP shunt (Codmans with siphonguard)	Shunt malposition	4-6 months	revise VP shunt (peritoneal end)	improve
7	77	none	DESH	6	2	VP shunt (medtronic)	Shunt malfunction	4-6 months	revise VP shunt	improve
8	74	Alzheimer disease, PD	non-DESH	12	5	VP shunt (Codmans with siphonguard)	shunt overdrainage with SDH	4-6 months	-	not improve
9	81	DM, HT, DLP, old CVA	non-DESH	8	4	VP shunt (Codmans with siphonguard)	shunt overdrainage with SDH	4-6 months	Burr holes craniostomy with drainage	improve
10	77	DM, HT, BPH, IHD	DESH	8	4	LP shunt	Shunt malfuction	1 year	Revise LP shunt	improve
11	76	HT, DLP, old CVA	DESH	9	4	LP shunt	Shunt malfunction	1 year	revise LP shunt (spinal	improve
12	78	old CVA, BPH	DESH	11	5	LP shunt	shunt overdrainage with SDH	1 year	-	not improve
13	78	old CVA	DESH	8	4	LP shunt	Shunt malfuction	2 years	Revise LP shunt	not improve
14	86	Alzheimer disease, HT, BPH, CKD	DESH	9	4	VP shunt (medtronic)	suspected shunt malfunction	2 years	-	not improve
15	71	HT, OA knee	DESH	8	4	LP shunt	suspected shunt malfunction	2 years	-	not improve
16	84	old CVA, HT, DLP, IHD, DVT	non-DESH	7	3	LP shunt	shunt malfunction	2 years	LP tap test then revise LP shunt	not improve

Table 4 Overall improvement after CSF shunting comparing non-DESH iNPH and DESH iNPH

Result	Total no. of pts	Non-DESH iNPH	DESH iNPH	*p*-Value
Result at first visit (no. of patients)	106	34	72	
No. of improvement		25 (73.5%)	64 (88.9%)	0.044

Table 5 Clinical outcome of iNPH patients at 4-6 months follow-up period comparing non-DESH iNPH and DESH iNPH groups

Parameter	Total no. (n=101)	Non-DESH iNPH (n=33)	DESH iNPH (n=68)	*p*-Value
iNPHGS, mean ±SD	7.10 ± 2.78	7.06 ± 2.72	7.11 ± 2.84	0.850
- No. of patients with positive outcome (%)	77.22%	72.7%	79.4%	0.452
mRS, mean ± SD	3.24 ± 1.13	3.18 ± 1.04	3.26 ± 1.18	0.651
- No. of patients with positive outcome (%)	51.48%	48.5%	52.9%	0.674
Improvement in bulbar symptoms (%)	57.47%	48.1%	61.7%	0.270
Improvement in neuropsychiatric symptoms (%)	51.19%	53.6%	50%	0.204

Results at 1 year after surgery

At this time, the total number of patients during this period was 92 (out of 106) patients. The improvement of both groups of iNPH patients seems to be stable at 1 year follow-up period as compared to the 4-6 month follow-up period (Table 6). The total number of patients with positive outcome during this period was 73.91%. There was slightly more improvement in the DESH group (79.7%) than in the non-DESH group (65.6%) but not statistically significant (p = 0.141). According to adverse events, there was a decrease in events during this time compared to the 4-6 months period.

Results at 2 years after surgery

At this time, the total number of patients during this period was 75 out of 106 patients. The clinical of iNPH patients have slightly deteriorated at 2 years after surgery. Seventy-five out of 106 preoperative patients (70.75%) had continued this study with

Table 6 Clinical outcome of iNPH patients at 1 year follow-up period comparing non-DESH iNPH and DESH iNPH

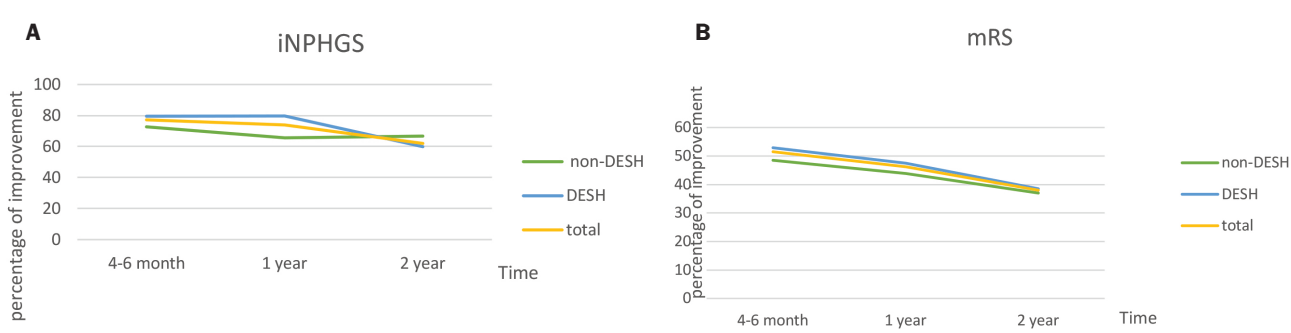
Parameter	Total no. (n=92)	Non-DESH iNPH (n=32)	DESH iNPH (n=60)	*p*-Value
iNPHGS, mean ±SD	6.83 ± 3.23	7.42 ± 2.69	6.54 ± 3.45	0.392
- No. of patients with positive outcome (%)	73.91%	65.6%	79.7%	0.141
mRS, mean ± SD	3.32 ± 1.16	3.28 ± 1.14	3.34 ± 1.18	0.640
- No. of patients with positive outcome (%)	45%	43.8%	47.5%	0.735
Improvement in bulbar symptoms (%)	53.5%	52.2%	54.2%	0.956
Improvement in neuropsychiatric symptoms (%)	45.7%	53.8%	40.0%	0.338

mean ± SD of iNPHGS of 6.88 ± 3.51 and mean ± SD of mRS of 3.52 ± 1.20. The percentage of patients who improved in bulbar symptoms and neuropsychiatric symptoms seems to decrease at this 2-year follow-up period (39.6% and 38.4%respectively) as shown in Table 7. There was an increase in adverse events during this time (compared to the 1 year).

Table 7 Clinical outcome of iNPH patients at 2 years follow-up period comparing non-DESH iNPH and DESH iNPH

Parameter	Total no. (n=75)	Non-DESH iNPH (n=27)	DESH iNPH (n=48)	*p*-Value
iNPHGS, mean ±SD	6.88 ± 3.51	7.32 ± 2.64	6.68 ± 3.84	0.930
- No. of patients with positive outcome (%)	65.3%	66.7%	59.6%	0.540
mRS, mean ± SD	3.52 ± 1.20	3.37 ± 1.07	3.60 ± 1.27	0.215
- No. of patients with positive outcome (%)	40.0%	37%	38.5%	0.902
Improvement in bulbar symptoms (%)	39.6%	41.2%	39%	0.850
Improvement in neuropsychiatric symptoms (%)	38.4%	50.0%	33.3%	0.440

According to the number of patients and iNPHGS improvement, there was more improvement in DESH iNPH group at 4-6 months (79.4% vs 72.7% in non-DESH) and 1 year (79.7% vs 65.6% in non-DESH) but reverse in 2 years (59.6% in DESH vs 66.7% in non-DESH) without statistic significant (Figure 2). According to mRS, there was a decline in the number of patients improved in both groups at 4-6 months, 1 year, and 2 years (52.9%, 47.5%, and 38.5% in the DESH group and 48.5%, 43.8%, and 37% in non-DESH group, respectively) with more improvement in DESH group (Figure 4A and B) but with no statistically significant.



number of improvements (%) over time according to iNPHGS

number of improvements (%) over time according to iNPHGS

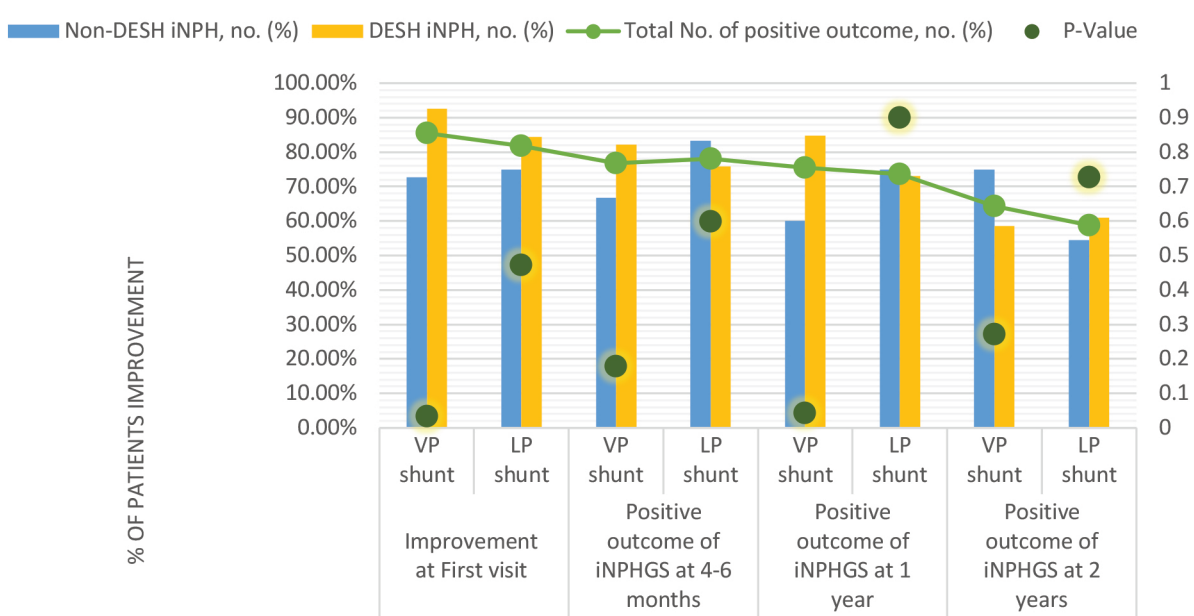
Figure 4 **A:** Showing the number of improvements (%) over time according to iNPHGS
B: Showing the number of improvements (%) over time according to mRS

Comparison of results between VP shunt and LP shunt surgery (a positive outcome of iNPHGS)

Concerning types of shunt surgery, the clinical improvement of VP shunt and LP shunt was highest at the first visit and decreased at the following 4–6 months visit, 1–year visit until the 2 years follow–up period. There were no differences in overall outcomes over time of both types of surgery (VP shunt vs LP shunt) as described in Figure 5. Subgroup analysis showed more improvement in the DESH group with VP shunt surgery at the first visit (92.5% vs 72.7% in non–DESH, p = 0.034) and 1 year after surgery (84.8% vs 60% in non–DESH, p = 0.042).

Prediction factors with a positive outcome of iNPHGS

All comorbidities (underlying conditions) were analyzed according to postoperative iNPHGS improvement. The comorbidity which had a positive predictive value of shunt outcome was no history of Alzheimer's disease or dementia, no history of diabetes mellitus, and no previous ischemic heart disease as shown in Table 8. The iNPH patients without Alzheimer's disease had significant positive outcomes 88.9%, 89.9%, and 92% at 4–6 months, 1–year visits, and 2 years, respectively. The patient without underlying DM (78.8%; p = 0.035) and without previous ischemic heart disease had positive outcomes at a 1year follow–up period (89.9%; p = 0.025)



	VP shunt	LP shunt	VP shunt	LP shunt	VP shunt	LP shunt	VP shunt	LP shunt
	Improvement at First visit		Positive outcome of iNPHGS at 4-6 months		Positive outcome of iNPHGS at 1 year		Positive outcome of iNPHGS at 2 years	
Non-DESH iNPH, no. (%)	72.70%	75%	66.70%	83.30%	60.00%	75.00%	75.00%	54.50%
DESH iNPH, no. (%)	92.50%	84.40%	82.10%	75.90%	84.80%	73.10%	58.60%	60.90%
Total No. of positive outcome, no. (%)	85.50%	81.80%	76.70%	78.00%	75.50%	73.70%	64.40%	58.80%
P-Value	0.034	0.473	0.179	0.599	0.042	0.9	0.272	0.726

Figure 5 Comparative outcome of iNPH patients treated with VP shunt and LP shunt in non–DESH and DESH iNPH

Table 8 Prediction factors with a positive outcome of iNPHGS composed of Alzheimer's disease/ dementia, DM and ischemic heart disease.

Underlying conditions	Positive outcome at 4–6 months (%)	*P*–Value	Positive outcome at 1 year (%)	*P*–Value	Positive outcome at 2 years (%)	*P*–Value
Without a history of Alzheimer's disease/Dementia	88.9	0.071	89.9	0.025	92	0.054
Without a history of Diabetes Mellitus	72.8	0.135	76.8	0.035	76.0	0.131
Without a history of Ischemic heart disease	86.4	0.646	89.9	0.025	86.0	0.933

Comparison between baseline iNPHGS with a positive outcome at 4-6 months and 1 year after surgery

The baseline clinical (iNPHGS) of the patient was analyzed to predict outcomes after surgery. There was a significant improvement in the number of patients with baseline iNPHGS scores between 7 and 9 at 4–6 months follow–up period and one year after surgery (Figure 6). Showing pre–operative iNPHGS compared to shunt responsive and non–responsive group at 4 months and 12 months follow up period

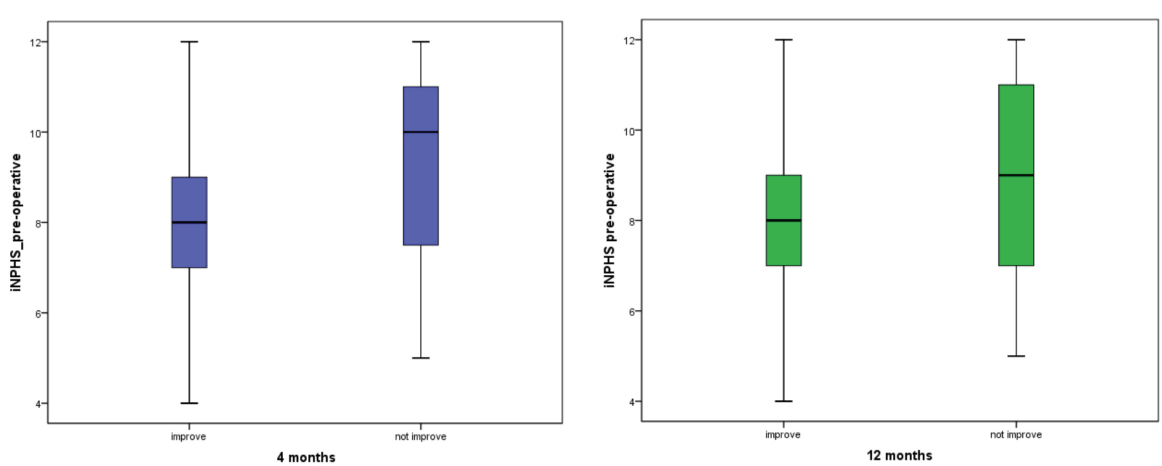


Figure 6 Showing pre–operative iNPHGS compared to shunt responsive and non–responsive group at 4 months and 12 months follow up period

Discussion

This study was a retrospective study to compare the outcome of surgical treatment of either VP shunt and LP shunt in iNPH patients who were classified into two groups: DESH iNPH and non–DESH group. According to the grouping of patients, there might be some conflict in the diagnosis of DESH due to lacking a good measurement tool to differentiate both groups. Some proposed measurement scoring called "DESH score"[15,16] to evaluate the DESH pattern includes five domains of the score (from 0–2): 1.) Evan's index 2.) Dilatation of Sylvian fissures 3.) tightness high convexity 4.) acute callosal angle and 5.) focal sulcal

dilation which is higher in total score show to have a high positive predictive value for improvement. This study has not applied this tool because of the inadequate quality of brain imaging in the medical record, as a result of brain MRI performed in some iNPH patients. According to preoperative baseline status, there was no statistical difference in patient characteristics at baseline between DESH iNPH and non-DESH iNPH group, except for Parkinson's disease and Alzheimer's disease. There were higher proportions of those diseases in the non-DESH group because the non-DESH group has not met the criteria for the diagnosis of DESH pattern upon imaging except for ventricular dilation. Clinical normal pressure hydrocephalus was also similar in Parkinson's and Alzheimer's disease, thereupon no finding of DESH upon imaging was hardly distinguishing between iNPH and other neurodegenerative diseases. In the previous study, Danielle et al.[20], reported 89% of NPH patients co-existed with Alzheimer's disease on autopsy. Jonathan et al.[21], reported 19% of NPH patients with concomitant Alzheimer's pathology based on brain biopsy at shunting time. Neill[22] reported about 30% of patients with NPH could have coexisting AD pathology. However, there was no difference in the patient's clinical at baseline between the two groups.

According to the number of patients, there was a decreased number of patients during the follow-up period (Figure 2). We suspected that some patients might lose follow-up, and some might have comorbidity and/or decreased over time due to most of the patients being elderly patients and some having serious comorbid which could affect patient status. As shown in adverse outcomes after surgery (Figure 3), there was an increase in adverse outcomes over time as high as 30.6% at 2 years follow-up (overall complications). As Alberto[23] reported over 40% of patients experienced at least one post-VPS complication. This study found a low incidence (5.8%) of shunt-related complications (as described in Table 3). There was a limitation of this study due to respective chart reviews and not mentioning the reasons for the patient loss in the medical record.

This study applied iNPHGS[19] for the measure of outcome and mRS for assessing functional status. According to iNPHGS, there were three domains with a score of 0-4 including a) cognitive impairment, b) gait disturbance and c) urinary disturbance. For the gait score, it seemed similar to mRS such as a score of 4 in iNPHGS defined as walking not possible that might equal to mRS score of 5. We found no statistical difference in baseline iNPHGS and mRS in both groups (Table 2). The mean iNPHGS of all patients was 8.70 ± 1.98 with a mean gait score of 3.05 ± 0.72 which means that the average of patients walked without any support. For mRS, the mean score was 3.77 ± 0.94 which means that the average of patients had moderate to severe disability and require help. We also collected bulbar and neuropsychiatric symptoms but there was limited data due to incomplete medical records.

According to outcomes after surgery, there was an overall improvement in both two groups with a better outcome in DESH iNPH group at the first visit (88.9% vs. 73.5%, p = 0.04) and 1 year (79.7% vs. 65.6%, p = 0.14 with another group) but no statistic difference at 4-6 month (72.7% vs. 79.4, p = 0.45) and 2 years after surgery (66.7% vs 59.6%, p = 0.54). Compared with the previous study, Ishikawa et al.[17], reported a high improvement of 73.5% in the DESH group compared to 63.6% in the non-DESH group at early visits after discharge. Craven et al.[18], reported 77% of the DESH positive group vs 75%

DESH negative group had a response to shunt surgery during a one-year postoperative period. Our study demonstrated in the non-DESH group also had a fair outcome at any time after surgery. The hypothesis is a diagnosis of DESH on imaging still lacked criteria or cut-off points to diagnosis and operator dependent. Patients with the non-DESH group still had clinical normal pressure hydrocephalus, the treatment with shunting might improve CSF circulation[24] and clinical NPH. According to a long-term outcome study, there was one meta-analysis[23] showed controversy in outcomes after shunt surgery. Some reported long-term outcomes after 36 months and showed sustained improvement between 40-73%[22,23]. As in our study, the improvement of shunt surgery at 24 months was 65.3% similar to those studies.

In our study, we found no overall difference in the outcome of any type of shunting surgery at the first visit (85.5% of VPS vs 81.8% of LPS), 4-6 months (76.7% of VPS vs 78% of LPS), 1 year (75.5% of VPS vs 73.7% of LPS) and 2 years (64.4% of VPS vs 58.8% of LPS). Miyajima[10] reported a 75% improvement in iNPHGS in the LP shunt group in 1 year which was comparable to 77% in the VP shunt group. Giordan[25] also reported a 75% improvement in patients after shunting. In subgroup analysis, we found that VP shunt surgery had a better outcome in the DESH group at the first visit (92.5% vs 72.7% in non-DESH, p = 0.03), 4-6 months (82.1% vs 66.7% in non-DESH, p = 0.17) and 1 year (84.8% vs 60% in non-DESH, p = 0.04). According to Ishikawa[17], the study found high improvement in the DESH group, as mentioned above.

According to the patient condition at baseline, we found that patients with no history of Alzheimer's disease, DM, and ischemic heart disease had better positive outcomes, especially 1 year after surgery. We found high improvement of iNPHGS at 1 year 89.9% in the non-Alzheimer group (p = 0.025), 76.8% in the non-DM group (p = 0.035), and 89.9% in the non-ischemic heart group (p = 0.025). Hudson reported 15.7-17.8% of patients with iNPH had Co-morbidity of diabetes mellitus and might have unfavorable outcomes after surgery. Okko[26] also reported that increased risk of death in patients with DM type 2. For patients without Alzheimer's, there was a better outcome at any time after surgery. Pomeneraniec[21] found that NPH patients with concomitant Alzheimer's disease had lower improvement (18.2%) after surgery. We hypothesized that NPH with AD might have a progression of Alzheimer's disease that could make the patient's condition worsen.

In our study, we found patients with preoperative iNPHGS scores of 7-9 had better positive outcomes than others. We also found patients with preoperative iNPHGS scores of 9-11 had poorer outcomes, especially at 4-6 months and 1 year after surgery. It might be because the patient with high iNPHGS at baseline had poor functional status with many underlying conditions. That might affect the improvement of a score. Most of the patients with high iNPHGS were bed-bound patients at baseline with some having stiffness of joint, surgery might not improve functional outcome but improve minor clinical statuses such as consciousness or bulbar symptoms.

The study's limitations arose from the retrospective nature of the chart review and a significant percentage of patients who were lost to follow-up, which could impact

the surgical outcomes. A further prospective study should be provided in the future with more long-term outcomes and study in the cost-effectiveness of surgery.

Conclusions

All patients with a diagnosis of iNPH should receive surgical treatment with or without DESH findings on radiographic imaging. There was a favorable positive outcome with minor shunt-related complications until at least 2 years after surgery. There were no differences between any shunting surgery at any time (either VP or LP shunt).

Acknowledgment

The authors gratefully acknowledge Ms.Nerisa Thornsri, Clinical Epidemiology Unit, Office of Research and Development, Faculty of Medicine Siriraj Hospital, Mahidol University, for assistance with statistical analysis.

Conflict of interest

The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. (NESDB), N.E.a.S.D.B. *Older statistic*. 2019 [cited 2019; Available from: http://social.nesdc.go.th/SocialStat/StatReport_Final.aspx?reportid=697&template=2R1C&yeartype=M&subcatid=116.
2. Muangpaisan W, Petcharat C, Srinonprasert V. Prevalence of potentially reversible conditions in dementia and mild cognitive impairment in a geriatric clinic. Geriatr Gerontol Int. 2012;12(1):59-64.
3. Evans Wa. An Encephalographic Ratio For Estimating Ventricular Enlargement And Cerebral Atrophy. *Arch NeurPsych*. 1942;47(6):931-937.
4. Relkin N, Marmarou A, Klinge P, Bergsneider M, Black PM. Diagnosing idiopathic normal-pressure hydrocephalus. Neurosurgery. 2005;57(3 Suppl):S4-16; discussion ii-v.
5. Halperin JJ, Kurlan R, Schwalb JM, Cusimano MD, Gronseth G, Gloss D. Practice guideline: Idiopathic normal pressure hydrocephalus: Response to shunting and predictors of response: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. Neurology. 2015;85(23):2063-71.
6. Mori E, Ishikawa M, Kato T, Kazui H, Miyake H, Miyajima M, et al. Guidelines for management of idiopathic normal pressure hydrocephalus: second edition. Neurol Med Chir (Tokyo). 2012;52(11):775-809.
7. Bovonsunthonchai S, Witthiwej T, Ngamsombat C, Sathornsumetee S, Vachalathiti R, Muangpaisan W, et al. Effect of spinal tap test on the performance of sit-to-stand, walking, and turning in patients with idiopathic normal pressure hydrocephalus. Nagoya J Med Sci. 2018;80(1):53-60.
8. Andersson J, Rosell M, Kockum K, Söderström L, Laurell K. Challenges in diagnosing normal pressure hydrocephalus: Evaluation of the diagnostic guidelines. eNeurologicalSci. 2017;7:27-31.
9. Bergsneider M, Black PM, Klinge P, Marmarou A, Relkin N. Surgical management of idiopathic normal-pressure hydrocephalus. Neurosurgery. 2005;57(3 Suppl):S29-39; discussion ii-v.
10. Miyajima M, Kazui H, Mori E, Ishikawa M; , on behalf of the SINPHONI-2 Investigators. One-year outcome in patients with idiopathic normal-pressure hydrocephalus: comparison of lumboperitoneal shunt to ventriculoperitoneal shunt. J Neurosurg. 2016;125(6):1483-92.
11. Jo KW, Kim Y, Park GY, Park IS, Jang Y, Gyun SD, et al. Oropharyngeal dysphagia in secondary normal pressure hydrocephalus due to corticobulbar tract

compression: cases series and review of literature. Acta Neurochir (Wien). 2017;159(6):1005-11.
12. Chankaew E, Srirabheebhat P, Manochiopinig S, Witthiwej T, Benjamin I. Bulbar dysfunction in normal pressure hydrocephalus: a prospective study. Neurosurg Focus. 2016;41(3):E15.
13. Peterson KA, Savulich G, Jackson D, Killikelly C, Pickard JD, Sahakian BJ. The effect of shunt surgery on neuropsychological performance in normal pressure hydrocephalus: a systematic review and meta-analysis. J Neurol. 2016;263(8):1669-77.
14. Jaraj D, Wikkelsø C, Rabiei K, Marlow T, Jensen C, Östling S, et al. Mortality and risk of dementia in normal-pressure hydrocephalus: A population study. Alzheimers Dement. 2017;13(8):850-7.
15. Radovnicky, T., Adamek, D., Derner, M. Sames M. Disproportionately enlarged subarachnoid space hydrocephalus presence in patients with idiopathic normal pressure hydrocephalus. *Fluids Barriers CNS* 2015;12 (Suppl 1), P43.
16. Shinoda N, Hirai O, Hori S, Mikami K, Bando T, Shimo D, Kuroyama T, Kuramoto Y, Matsumoto M, Ueno Y. Utility of MRI-based disproportionately enlarged subarachnoid space hydrocephalus scoring for predicting prognosis after surgery for idiopathic normal pressure hydrocephalus: clinical research. J Neurosurg. 2017;127(6):1436-42.
17. Ishikawa M, Oowaki H, Takezawa M, Takenaka T, Yamada S, Yamamoto K, et al. Disproportionately Enlarged Subarachnoid Space Hydrocephalus in Idiopathic Normal-Pressure Hydrocephalus and Its Implication in Pathogenesis. Acta Neurochir Suppl. 2016;122:287-90.
18. Craven CL, Toma AK, Mostafa T, Patel N, Watkins LD. The predictive value of DESH for shunt responsiveness in idiopathic normal pressure hydrocephalus. J Clin Neurosci. 2016;34:294-8.
19. Kubo Y, Kazui H, Yoshida T, Kito Y, Kimura N, Tokunaga H, et al. Validation of grading scale for evaluating symptoms of idiopathic normal-pressure hydrocephalus. Dement Geriatr Cogn Disord. 2008; 25(1):37-45.
20. Cabral D, Beach TG, Vedders L, Sue LI, Jacobson S, Myers K, Sabbagh MN. Frequency of Alzheimer's disease pathology at autopsy in patients with clinical normal pressure hydrocephalus. Alzheimers Dement. 2011;7(5):509-13.
21. Pomeraniec IJ, Bond AE, Lopes MB, Jane JA Sr. Concurrent Alzheimer's pathology in patients with clinical normal pressure hydrocephalus: correlation of high-volume lumbar puncture results, cortical brain biopsies, and outcomes. J Neurosurg. 2016;124(2):382-8.
22. Graff-Radford NR, Jones DT. Normal Pressure Hydrocephalus. Continuum (Minneap Minn). 2019;25(1):165-86.
23. Espay AJ, Da Prat GA, Dwivedi AK, Rodriguez-Porcel F, Vaughan JE, et al. Deconstructing normal pressure hydrocephalus: Ventriculomegaly as early sign of neurodegeneration. Ann Neurol. 2017;82(4):503-13.
24. Lalou AD, Czosnyka M, Donnelly J, Pickard JD; FMedSci; Nabbanja E, Keong NC, Garnett M, Czosnyka ZH. Cerebral autoregulation, cerebrospinal fluid outflow resistance, and outcome following cerebrospinal fluid diversion in normal pressure hydrocephalus. J Neurosurg. 2019;130(1):154-62.
25. Giordan E, Palandri G, Lanzino G, Murad MH, Elder BD. Outcomes and complications of different surgical treatments for idiopathic normal pressure hydrocephalus: a systematic review and meta-analysis. J Neurosurg. 2018;131(4):1024-36.
26. Pyykkö OT, Nerg O, Niskasaari HM, Niskasaari T, Koivisto AM, Hiltunen M, et al. Incidence, Comorbidities, and Mortality in Idiopathic Normal Pressure Hydrocephalus. World Neurosurg. 2018;112:e624-e631.

Thai J Neurol Surg 2024;15(1):24-41.

Research Article

Clinical and Radiographic Outcomes of Atlanto-Axial Screw Fixation in Neurological Institute of Thailand

Aiayarch Tanawarangkoon, M.D.
Teera Tangviriyapaiboon, M.D.
Department of Neurological Surgery, Neurological Institute of Thailand

Abstract

Background and Objective: There are many techniques for atlanto-axial fixation such as posterior wiring technique with bone graft fusion, transarticular screwC1-2 fixation, C1 lateral mass with C2 pedicle screw fixation secured by rigid plate or connected by rod system, and modified techniques for C2 screw fixation. The objective of the present study is to compare clinical and radiographic outcomes of patients treated with transarticular screws (TAS) and screw-rod constructs (SRC) for posterior atlantoaxial fusion and subgroup analysis compare clinical and radiographic outcomes of patients treated with translaminar C1 lateral mass screw and sublaminar C1 lateral mass screw of the SRC group.

Material and Method: A retrospective charts review were performed using operative database and imaging records to identify all patients who underwent C1-2 screw rod construction or C1-2 transarticular screw fixation between February 2008 and December 2016 at Neurological Institute of Thailand. Forty-two patients in total were analyzed for clinical and radiographic outcomes. The patients were divided into 2 group: 9 patients in transarticular screw (TAS) fixation and 33 patients in screw rod construct (SRC). In addition, the patients in the SRC group were divided into two groups: 10 patients who were treated with translaminar C1 lateral mass screw and 19 patients who were treated with sublaminar C1 lateral mass screw.

Result: Forty-two patients were included in the present study, there are no statistically significant differences were found between the TAS and the SRC groups in ΔADI [0.82 (-0.29-4.87) VS 0.05 (0-1.75), *P* = 0.488], ΔPADI [1.20 (-0.77-4.52) VS 0.05 (0-1.26), *P* = 0.554], ΔNDAASC [1.85(0.87-6.16) VS 1.67(0.34-5.20), *P* = 0.46], ΔNDAASC% [13.45 (5.35-79.59) VS 13.39 (1.89-50.73), *P* = 0.594], operative time [150 (132.5-347.5) min VS 203 (157-254.5) min, *P* = 0.453], Blood loss [200 (100-500) ml VS 250 (135-400) ml, *P* = 0.963] and hospital stay [14 (8.5-24) days VS 10 (6.5-17) days, *P* = 0.167], postoperative NCSS at 1 year (*P* = 0.438), the percentage of postoperative NCSS at 1 year (*P* = 0.419) and postoperative JOA score at 1 year (*P* = 0.418). In the subgroup analysis of the SRC group, there was no statistically significant difference between the two groups in ΔADI [0.46 (0-2.91) VS 0.02 (0-0.81), *P* = 0.454], ΔPADI [0.36 (-0.47-1.57) VS 0.05 (0-0.66), *P* = 0.947],

Corresponding author: **Teera Tangviriyapaiboon, M.D.**
Department of Neurological Surgery, Neurological Institute of Thailand, Bangkok, Thailand

ΔNDAASC [1.28(0.24-3.92) VS 3.17(0.35-5.63), *P* = 0.461], ΔNDAASC % [6.57(1.67-30.77) VS 22.43 (1.56-62.98), *P* = 0.357], postoperative JOA score at 1 year (*P* = 0.381), postoperative NCSS at 1 year (*P* = 0.858) and the percentage of postoperative NCSS at 1 year (*P* = 0.953). Only one patient in the SRC group with sublaminar C1 lateral mass screw technique was found with postoperative occipital neuralgia and 2 patients in the SRC group with sublaminar C1 lateral mass screw technique were found with broken screws.

Conclusion: Both TAS and SRC techniques can be used for C1-2 instability since no statistically significant results were found in both group and there was low incidence of complication. Sublaminar and translaminar C1 lateral mass screw techniques showed no statistically significant differences even though sublaminar C1 lateral mass screw technique seems to yield a slightly higher rate of occipital neuralgia. The decision to use either technique of C1-2 fixation must be made after careful review of the individual patient's anatomy on imaging and the surgeon's experiences.

ADI = atlanto-dental interval, ΔADI= differences between ADI, PADI = posterior atlanto-dental interval, ΔPADI= differences between PADI, NDAASC = narrowest in A-P diameter of atlantoaxial spinal canal, ΔNDAASC= differences between NDAASC,ΔNDAASC%= percentage of differences between NDAASC, NCSS= Neurosurgical cervical spine scale14, JOA score= Japanese Orthopaedic Association score15.

Introduction

There are multiple techniques for atlanto-axial instability such as posterior wiring technique with bone graft as described by Gallie, Brooks, and Jenkins, and Dickman and Sonntag et al. Magerl and Jeanneret described transarticular screw fixation in 1979, many years later Goel and Laheri reported C1 lateral mass and C2 pedicular screws secured by rigid plate in 1994. Recently, Harms and Melcher modified Goel technique by using polyaxial C1 lateral mass and C2 pedicle screws connected by rod in 2001 [1, 2.]

Initially, C1-2 fixation is conducted by resecting nerve root, which has been found to cause higher incidence of occipital numbness. Consequently, the technique is later modified by preserving the C2 nerve root to reduce the said complication. However, higher incidence of occipital neuralgia is instead found when the C2 nerve root is preserved[3,4]. As a result, posterior arch C1 technique (translaminar C1 lateral mass screw) is then used to avoid C2 nerve root and to reduce blood loss due to venous plexus bleeding [2,5,6].

The objective of the present study was to compare clinical and radiographic outcomes of patients treated with transarticular screws (TAS) and screw-rod constructs (SRC) for posterior atlantoaxial fusion and to compare clinical and radiographic outcomes of patients treated with translaminar C1 lateral mass screw and sublaminar C1 lateral mass screw of the SRC group.

Method

A retrospective chart review was performed using operative database and imaging records to identify all patients who underwent C1-2 screw rod construction or C1-2 transarticular screw fixation

between 1st February 2008 and 1st December 2016 at Neurological Institute of Thailand. Included patients were treated by C1-2 transarticular screw fixation and screw rod construct technique, excluded patient were treated by other procedures such as wiring or occipito-cervical fixation. In total, 42 patients were divided into 2 group; 9 patients in transarticular screw (TAS) fixation and 33 patients in screw rod construct (SRC)]. The patients in the SRC group were divided into two groups: 10 patients who were treated with translaminar C1 lateral mass screw and 19 patients who were treated with sublaminar C1 lateral mass screw.

The first priority surgical technique of atlantoaxial fixation in Neurological Institute of Thailand is TAS unless the following conditions: (1) uncorrectable C1-2 alignment and/or irreducible of C1-2 dislocation (2) small pars or high riding vertebral artery (3) defected of posterior arch C1 (4) short neck and large shoulder, which cannot be positioned for transarticular screw trajectory (5) patients refused to use iliac bone graft for wiring in the TAS technique. Demographic information of all patients was collected including gender, age, clinical presentation, duration of symptom. Preoperative evaluation data collected included causes of C1-2 instability, odontoid fracture, types of odontoid fracture, atlanto-dental interval (ADI), posterior atlanto-dental interval (PADI) and new parameter such as narrowest in A-P diameter of atlantoaxial spinal canal (NDAASC) at sagittal view of bone windows on CT scan, preoperative Japanese Orthopedic Association Score (JOA) and Neurosurgical cervical spine scale (NCSS). These collected data were then evaluated to compare clinical outcomes. Intraoperative variables collected included C1-2 fixation technique, operative blood loss (ml), the length of hospital stay. Postoperative variables were hardware failure (broken screw or rod /loosening screw), screw malposition, occipital neuralgia, occipital numbness, infection, differences between Preoperative and Postoperative ADI, differences between Preoperative and Postoperative PADI, differences between Preoperative and Postoperative AAMNSC, Fusion at 1 year after the surgery, postoperative clinical outcome at 1 year evaluated by Neurosurgical cervical spine scale(NCSS) and Japanese Orthopaedic Association (JOA) score.

Surgical Procedure

Transarticular screw technique

The patient is lying in a prone position in a Mayfield head holder (Radiolucent Mayfield) with the neck in a neutral position and flexion the head on the neck in a military tuck position (Figure 1)[1]. In an anteroposterior plane, take an open mouth view x-ray and lateral radiographs before start the operation in addition to confirm proper reduction of atlantoaxial joint to anatomical alignment, and also to locate the skin entry site for the screw trajectory. All patients are prepared and draped from the suboccipital to the mid thoracic area.

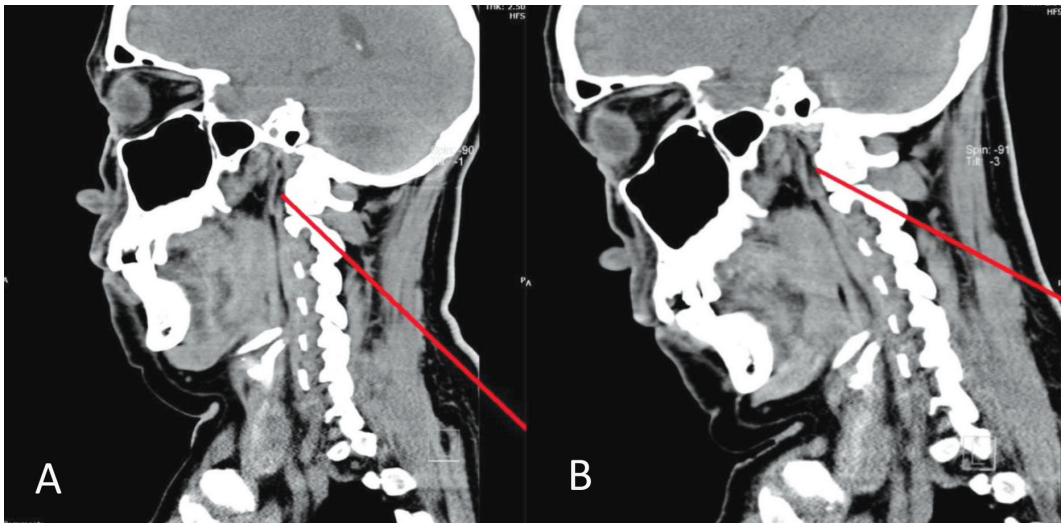


Figure 1 (A) Trajectory for a C1–2 transarticular screw if the patient is positioned without capital flexion of the head on the neck, which is a position unsuitable for the TAS technique.
(B) Trajectory for a C1–2 transarticular screw for a patient positioned with capital flexion of the head on the neck (military tuck position).

A separated midline incision is then created to expose the posterior elements of C1–C3, identify C2 lateral mass. Using No. 4 Penfield dissector, make a gentle sweeping movement C2 nerve in a rostral direction, pass Penfield dissector medially and superiorly over the pars and pedicle of C2 to determine the angle for the screw, control bleeding from epidural venous plexus on medial aspect of the pars by bipolar cautery and absorbable gelatin sponge packing.

With fluoroscopic guidance, the proper trajectory is confirmed by placing the drill or similar instrument adjacent to the neck outside of the incision by subcutaneous tunnel. This trajectory should cross the C1–C2 facet joint and end at the anterior arch of the atlas under biplane fluoroscopic vision. The percutaneous entrance site for the drill is determined, then stab incisions is created approximately 1 cm. from the midline bilaterally, a guide tube with an obturator is placed through the stab incision site and into the open surgical site at C1–C3. The tip of the guide tube is docked at the C2 entry site. The C2 entry site is identified by locating the inferior medial angle of the C2–C3 facet joint. The entry site is approximately 3 mm rostral and 3 mm lateral to these points (Figure 2). The cortical bone is drilled using a high speed-drill and marked for a K-wire entry site. The K-wire trajectory is typically 0–15 degrees medial with the superior angle visualized by fluoroscopy. The K-wire is directed down the C2 pars and pedicle complex and across the C1–C2 joint, aiming at the anterior tubercle of C1. After the K-wire is placed, drill at the same target point. A short threaded cancellous screw is placed (The screw was usually 1–3 mm shorter than the actual measured length since some degree of compression of the C1–2 joints occurs with screw placement). The same technique is repeated on the opposite side. Transarticular screw fixation with Sonntag posterior interspinous wiring procedure and iliac bone graft fusion1 are usually supplemented for added stability.

Translaminar lateral mass C1 technique or posterior arch C1 lateral mass technique (PALM) is used in patients with widening posterior arch of C1 and shallow sulcus arteriosus. The entry point for translaminar

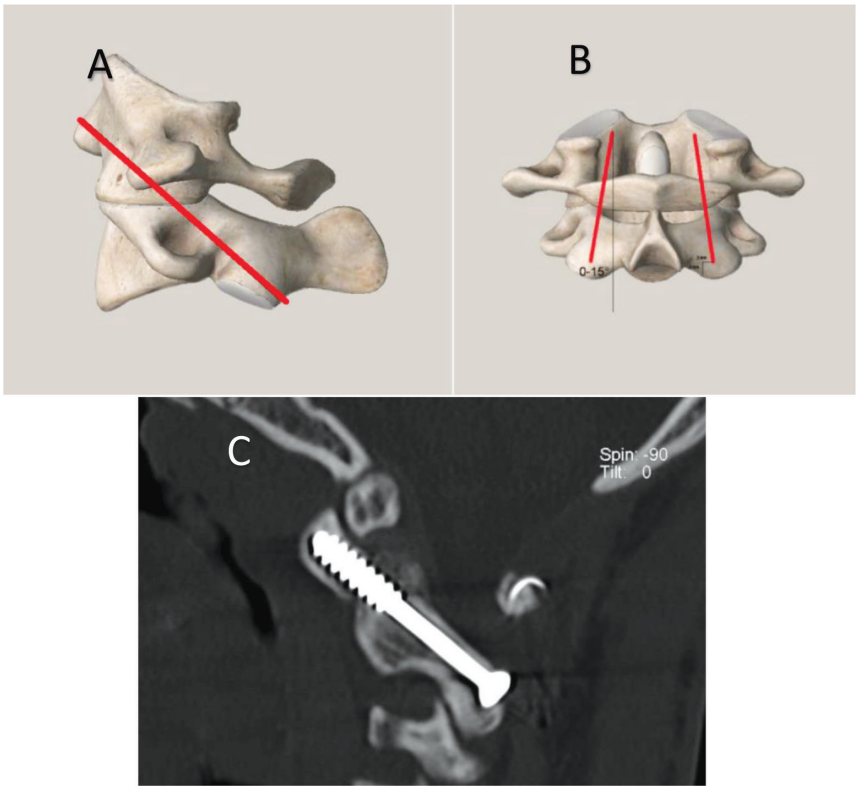


Figure 2 C1-2 Transarticular screw technique
(A) Lateral view: Trajectory for a C1-2 transarticular screw (red line).(B) Posterior view: Trajectory for a C1-2 transarticular screw (red line), The entry site is approximately 3 mm rostral and 3 mm lateral to the inferior medial angle of the C2-C3 facet joint, typically 15 degrees medial. (C) Sagittal CT scan showing C1-2 transarticular screw.

Screw rod construction technique

The patient is lying in the prone position in a Mayfield head holder (Radiolucent Mayfield). The neck is kept in neutral position. A midline incision is made from the suboccipital area to spinous process of C3. The C2-C3 facet joints are exposed and the dorsal arch of C1 is exposed, revealing the vertebral artery in the vertebral groove on the superior aspect of the C1 arch (sulcus arteriosus). The C2 nerve root is identified. Bipolar cautery and hemostatic agent is used to control bleeding from the venous plexus surrounding the C2 nerve root and mobilized C2 nerve root inferiorly. The medial wall of C1 lateral mass is identified using dissector to palpate the medial limit of screw placement. The medial aspect of the transverse foramen at C1 and C2 can also be identified and serve as a lateral limit for screw placement. The entry point for the C1 lateral mass screw is divided into two techniques, translaminar lateral mass C1 technique or posterior arch C1 lateral mass technique (PALM) and sublaminar C1 lateral mass screw technique or Goel/Harms C1 lateral mass technique (GHLM).

C1 lateral mass screw is identified at the center of the C1 lateral mass. Under fluoroscope guidance the screw track is drilled with a similar 10–15 degree medial angulation while perpendicular to the posterior arch. The location of vertebral artery is confirmed by the surgeon before drilling. The hole is then tapped and the screw is placed (Figure 3).

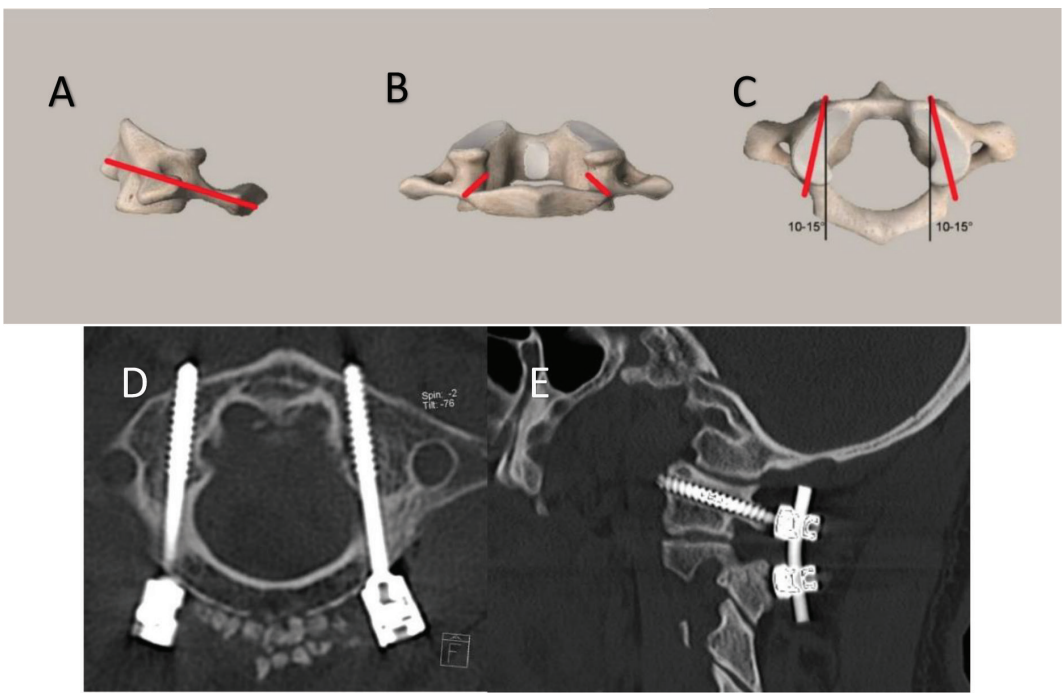


Figure 3 Translaminar C1 lateral mass screw technique
(A) Lateral view: Trajectory for a translaminar C1 lateral mass screw (red line), entry point at the center of the C1 lateral mass. (B) Posterior view: Trajectory for a translaminar C1 lateral mass screw (red line). (C) Superior view: Trajectory for a translaminar C1 lateral mass screws (red line), the entry site 10– 15 degree medial angulation while perpendicular to the posterior arch13. (D) Axial CT scan showing translaminar C1 lateral mass screws. (E) Sagittal CT scan showing translaminar C1 lateral mass screws.

For sublaminar C1 lateral mass screw technique or Goel/Harms C1 lateral mass technique (GHLM), the center of the C1 lateral mass and its intersection with the inferior portion of the lamina is identified and the screw track is drilled using fluoroscopic guidance at a 10–15 degree medial angulation, penetrating the anterior cortex of C1. The track is then tapped and the screw is placed. In this study, C2 nerve root is preserved in all patients. (Figure 4).

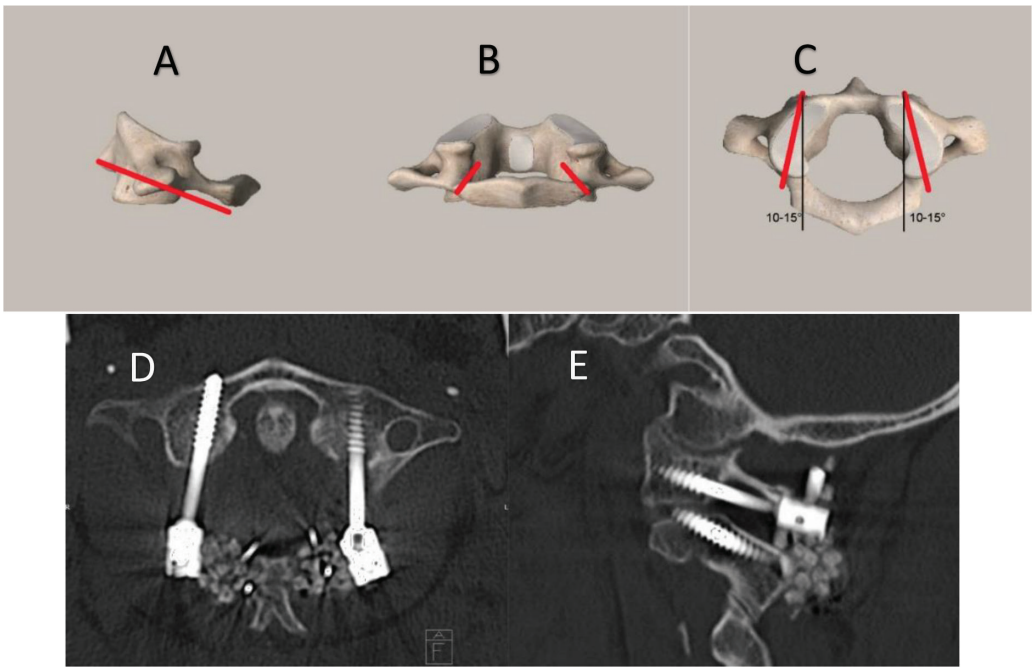


Figure 4 Sublaminar C1 lateral mass screw technique
(A) Lateral view: Trajectory for a sublaminar C1 lateral mass screw (red line), entry point at the center of the C1 lateral mass and its intersection with the inferior portion of the lamina. (B) Posterior view: Trajectory for a sublaminar C1 lateral mass screw (red line). (C) Superior view: Trajectory for a sublaminar C1 lateral mass screws (red line), the entry site 10- 15 degree medial angulation. (D) Axial CT scan showing sublaminar C1 lateral mass screws. (E) Sagittal CT scan showing sublaminar C1 lateral mass screws.

The C2 screw can be placed in pedicle, pars and lamina. The first choice of C2 screw fixation is transpedicular screw fixation for more contract surface of screw and bone. For C2 pedicle screw fixation, the entry point of C2 is targeted based on the transitional corner, which is the more cephalad portion of the lamina and the C2 isthmus. Using a high-speed drill, the entry point is marked 4 mm. lateral to and 4 mm. caudal to transitional point. The direction is approximately 20-30 degree in a medial and cephalad direction to the medial border at the C2 pars interarticularis under fluoroscopy guidance. After making a tapering hole, 3.5 mm. polyaxial screw is inserted (Figure 5). If the pedicle is small, the second choice will be pars screw. A C2 pars screw is placed in a trajectory similar to that of a C1-C2 transarticular screw, except that it is much shorter (Figure 6). If the pedicle is small and high riding vertebral artery, it is unsuitable to use pedicle screw and pars screw. Laminar screw should be used instead. The laminar screw C2, using crossing screw is placed directly onto the cancellous bone of the lamina of C2, a high-speed drill is then used to open a small cortical window at the junction of C2 spinous process and lamina on the right, close to the rostral margin of the C2 lamina.

With a hand drill, the contralateral lamina is drilled to 24–30 mm. depth. To avoid any injuries on the spinal canal, the trajectory of insertion is kept slightly less than the downslope of the lamina to ensure that any possible cortical breakthroughs occur dorsally through the laminar surface, rather than ventrally into the spinal canal. Additionally, a small ball probe is used to palpate the length of the hole to verify that no cortical breakthroughs into the spinal canal has occurred. Polyaxial screw is then inserted along the same trajectory. In the final position, the screw head is marked at the junction of the spinous process and C2 laminar on the left, close to the caudal aspect of the lamina. Using of the same technique as above, a screw is then placed onto the right lamina, with the screw head remaining on the left side of the spinous process (Figure 7).

Rods are contoured and then secured to the remaining screw heads in the construct. Local autograft or artificial bone graft are packed around the remaining exposed bone surfaces and into the decorticated facet complexes.

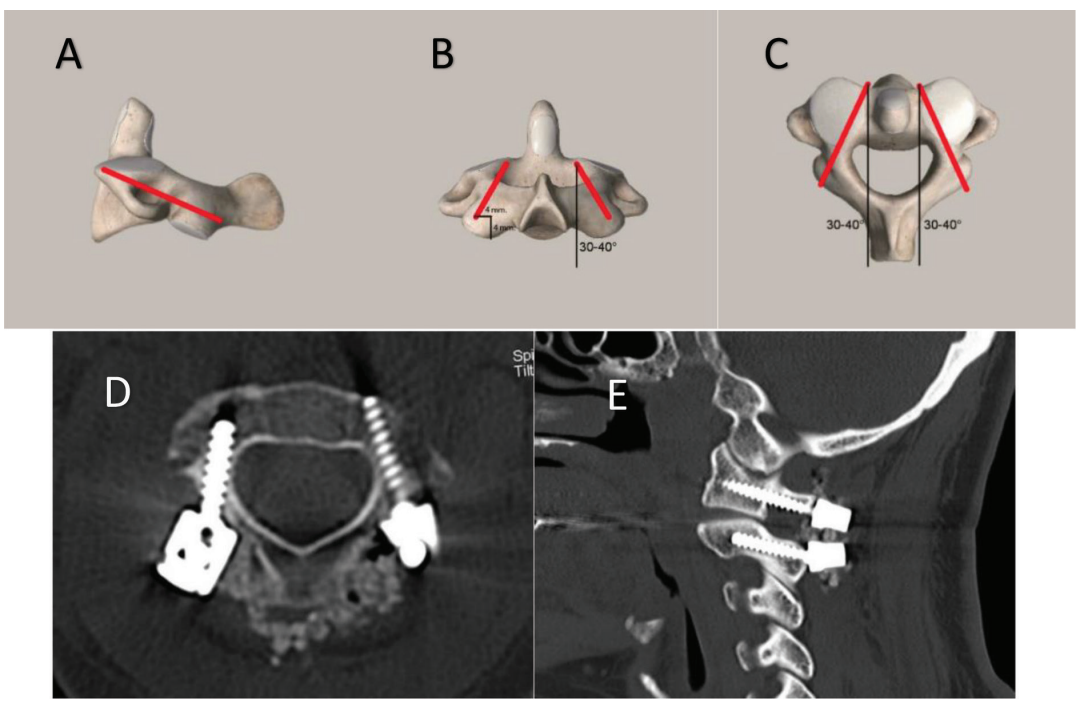


Figure 5 C2 pedicle screw technique

(A) Lateral view: Trajectory for C2 pedicle screw (red line). (B) Posterior view: Trajectory for C2 pedicle screw (red line), the entry points of C2 is marked 4 mm. lateral to and 4 mm. caudal to transitional point, which is the more cephalad portion of the lamina and the C2 ischmus. (C) Superior view: Trajectory for C2 pedicle screw (red line), The direction was approximately 20–30 degree in a medial and cephalad direction to the medial border at the C2 pars interarticularis. (D) Axial CT scan showing C2 pedicle screws. (E) Sagittal CT scan showing C2 pedicle screws.

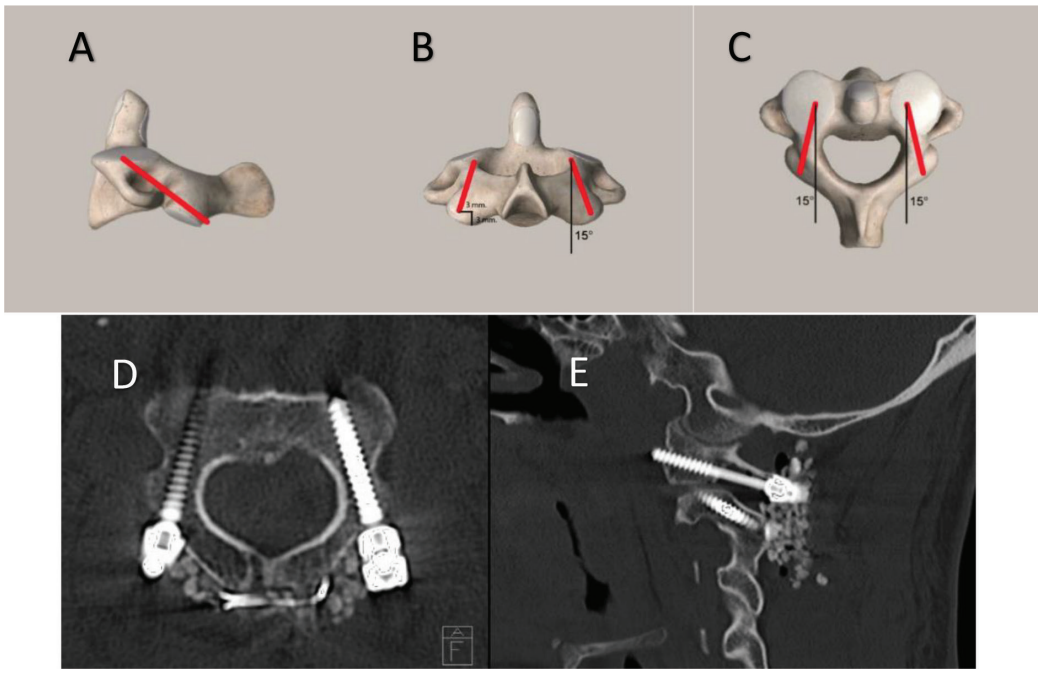


Figure 6 C2 pars screw technique
(A) Lateral view: Trajectory for C2 pars screw (red line). (B) Posterior view: Trajectory for C2 pars screw (red line), the entry site is approximately 3 mm rostral and 3 mm lateral to the inferior medial angle of the C2-C3 facet joint, typically 15 degrees medial. (C) Superior view: Trajectory for C2 pars screw (red line). (D) Axial CT scan showing C2 par screws. (E) Sagittal CT scan showing C2 pars screws.

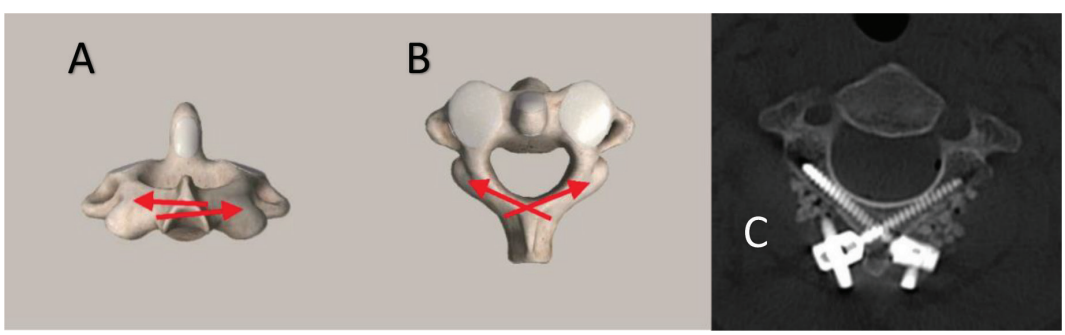


Figure 7 C2 laminar screw technique
(A) Posterior view: Trajectory for C2 pars screw (red arrow), using crossing screw placed directly onto the cancellous bone of the C2 lamina. Right side, the screw at rostral margin of the C2 lamina and the caudal aspect of the lamina at the left side. (B) Superior view: Trajectory for C2 pars screw (red arrow). (C) Axial CT scan showing C2 laminarscrews.

Radiographic evaluation

Plain film C-spine AP and lateral view and CT scan bone window is performed on all patients. The evaluated parameter in preoperative imaging were atlanto-dental interval (ADI), posterior atlanto-dental interval (PADI). The parameter was measured in neutral position. In this report, the narrowest anteroposterior (AP) diameters between C1-2 spinal canal viewed at sagittal view of CT bone was referred to as "narrowest in A-P diameter of atlantoaxial spi-

nal canal (NDAASC)". Postoperative data collected were ADI, PADI, NDAASC, differences between ADI (ΔADI), differences between PADI (ΔPADI), differences between NDAASC (ΔNDAASC), percentage of differences between NDAASC (ΔNDAASC%). (Figure 8)

Plain film C-spine AP and lateral view are performed all cases at postoperative 1-2 day and CT bone is performed on 37 patients (88%).

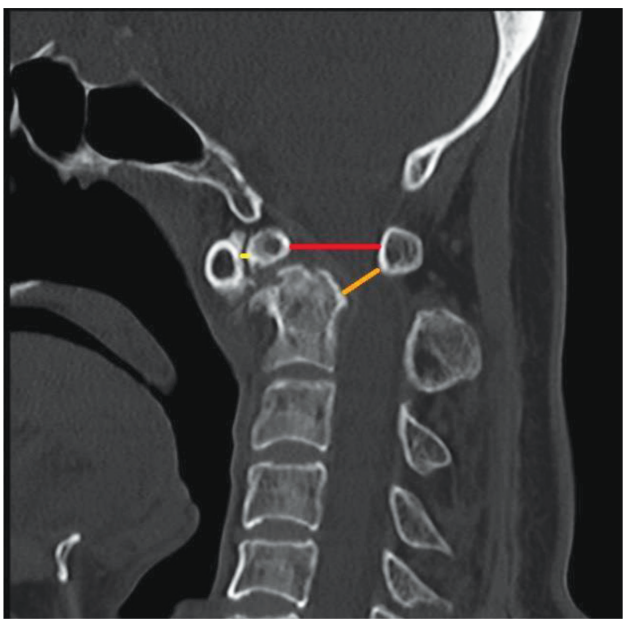


Figure 8 Radiographic parameter
1) Yellow line: Atlanto-dental interval (ADI)
2) Red line: Posterior atlanto-dental interval (PADI)
3) Orange line: Narrowest in A-P diameter of atlantoaxial spinal canal (NDAASC)

Follow-up and outcome

The median follow-up length was 1 year and 5 months (10 months – 3 years 7months).
Only patients who had been followed-up for at least one year were used for analysis.

Bony fusion is defined by 1) demonstrating bridging bone between C1-2 or continuous cortical bone between C1-2. 2) At flexion and extension plain film c-spine, with no movement of C1-2.

JOA and NCSS were used to compare preoperative and postoperative for each group and preoperative baseline and postoperative clinical outcome between the TAS and the SRC group.

The estimated NCSS percentage of improvement of the neurological status at the initial and follow-up examination can be calculated by the following formula:

$$A\ (\%) = (T_F - T_i / 14 - T_i) \times 100$$

A is percentage of improvement

T_i is total scores in the initial examination

T_F is total scores in the follow-up examination

Statistics analysis

Man-Whitney test was used for continuous variables and the Chi-square test for categorical variables. Wilcoxon signed ranks test was used to analyze the preoperative and postoperative continuous variables. Baseline characteristic data were used to derive the percentage for gender, and median with interquartile range was used for nonparametric univariate statistics for quantitative variables. Statistical significances in all analyses are defined at $p < 0.05$. All statistical analysis is performed using SPSS version 16.0.

Result

Patient Characteristics

Patient demographics were well balanced between the TAS and SRC groups (Table 1). Overall,

the vas majority of the patients in the present study were male (25, 59.5%), and their mean age was in the fourth decade of life. Causes of C1–2 instability were traumatic subluxation (50%), a non-traumatic subluxation (31%), infection (7.1%), Os odontoidium (4%), and rheumatoid (2.4%). The median duration of symptoms was 90 days (20–212). On admission, 20 patients (47.6%) suffered from neck pain only, 14 patients (33.3%) had neck pain with myelopathy, 7 patients (16.7%) had myelopathy only (only 1 of 7 was quadriplegia) and 1 patient (2.4%) was asymptomatic.

Table 1 Patient baseline characteristics in the transarticular screws (TAS) and the screw-rod constructs (SRC) group

	TAS (9)	**SRC (33)**	***P* value**
Sex			0.716
Male (%)	6(66.7)	19(57.6)	
Female (%)	3(33.3)	14(42.4)	
Age (median,year)	51(47-59)	47(34-64.5)	0.57
Onset duration (median,day)	90(11-365)	90(25.5-182)	0.746
Clinical Presentation			0.354
Neck pain	5	15	
Neck pain with myelopathy	2	12	
Myelopathy	1	6	
Asymtomatic	1	0	
Cause			0.145
Traumatic subluxation	6	15	
Non-traumatic subluxation	1	12	
Infection	2	1	
Os odontoidium	0	4	
Rheumatoid	0	1	
Odontoid Fracture			0.438
None	2	15	
Type I	1	4	
Type II	5	13	
Type III	1	1	
Preoperative ADI (mm.)	1.68(1.305-6.75)	1.62(0.905-5.73)	0.592
Preoperative PADI (mm.)	15.44(9.525-19.51)	16.57(12.56-20.065)	0.51
Preoperative NDAASC (mm.)	13.75(8.875-16.09)	12.8(9.525-16.495)	0.902
Preoperative NCSS	12(12-12)	12(10-12)	0.207
Preoperative JOA score			0.312
Grade 0 (16-17)	7	19	
Grade 1 (12-15)	1	12	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	1	2	

ADI: Atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.

TAS Versus SRC

Radiological result

The diagnosis was verified with plain film and CT scan in all patients and 24 patients (57%) had additional MRI scan preoperative.

Fracture odontoid process was present in 25 patients (59.5%), and widening ADI at neutral lateral plain film and neutral CT scan was present in 17 patients (40%). In all patients, the median of preoperative ADI was 1.65(1.095-6.21), preoperative PADI was 16.56(12.42-19.81) and preoperative NDAASC was 13.26(9.66-16.46).

No statistical significances were found in the comparison of TAS and SRC groups in ΔADI [0.82 (-0.29- 4.87) VS 0.05(0-1.75), *P* = 0.488], ΔPADI [1.20 (-0.77-4.52) VS 0.05(0-1.26), *P* = 0.554], ΔNDAASC [1.85 (0.87-6.16) VS 1.67 (0.34-5.20), *P* = 0.46], ΔNDAASC% [13.45 (5.35-79.59) VS 13.39 (1.89-50.73), *P* = 0.594]. (Table 2).

Table 2 Postoperative outcome in the transarticular screws (TAS) and the screw-rod constructs (SRC) group

	TAS (8)	SRC (33)	*P* value
ΔADI (mm.)	0.82 (-0.29-4.87)	0.05 (0-1.75)	0.488
ΔPADI (mm.)	1.20 (-0.77-4.52)	0.05 (0-1.26)	0.554
ΔNDAASC (mm.)	1.85 (0.87-6.16)	1.67 (0.34-5.20)	0.46
ΔNDAASC (%)	13.45 (5.35-79.59)	13.39 (1.89-50.73)	0.594
Fusion*	9 (100)	28 (96.6)	1
Postoperative NCSS 1 y**	14 (13-14)	14 (14-14)	0.438
Postoperative NCSS 1 y %**	100 (70-100)	100 (100-100)	0.419
Postoperative JOA score 1 y**			0.418
Grade 0 (16-17)	6	22	
Grade 1 (12-15)	1	1	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	0	0	

ADI: atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.

*Four patients were excluded in the SRC group due to no postoperative follow up imaging.

**Two patients in the TAS group and 10 patients in the SRC group were excluded due to discontinuity of follow-up before 1 year.

Follow up and outcome

No statistically significant differences were observed in operative time [150 (132.5-347.5) min VS 203 (157-254.5) min, *P* = 0.453], blood loss [200 (100-500) ml VS 250 (135-400) ml, *P* = 0.963] and hospital stay [14 (8.5-24) days VS 10 (6.5-17) days, *P* = 0.167] both TAS and SRC group, respectively. (Table 3)

Table 3 Intraoperative outcome of the transarticular screws (TAS) and the screw-rod constructs (SRC) group

	TAS (9)	SRC (33)	*P* value
Operative time (min)	150(132.5-347.5)	203(157-254.5)	0.453
Blood loss (ml)	200(100-500)	250(135-400)	0.963
Hospital Stay (day)	14(8.5-24)	10(6.5-17)	0.167

At the mean of the follow-up lengths of 3.55 and 1.3 years for the TAS and SRC groups, respectively, no statistically significant differences were observed in fusion [9 (100%) VS 28 (96.6%), *P* = 1], postoperative NCSS at 1 year (*P* = 0.438), percentage of postoperative NCSS at 1 year (*P* = 0.419) and postoperative JOA score at 1 year (*P* = 0.418). (Table 2)

In TAS technique, the comparison of preoperative and postoperative radiologic outcome in ADI showed no statistically significant results [1.68 (1.3-6.75) VS 1.77 (1.36-1.91), *P* = 0.11], which resembled the results found for PADI [15.44 (9.53-19.51) VS 17.18 (16.32-20.68), *P* = 0.208], while NDAASC showed significant widening spinal canal [13.75 (8.86-16.09) VS 16.03 (15.5-19.2), *P* = 0.008]. (Table 4)

Follow-up and outcome

In TAS technique, JOA at 1 year follow-up showed no statistically significant differences when compared to preoperative JOA while NCSS showed significant improvement at postoperative 1 year. (Table 4)

Table 4 Preoperative and postoperative comparison of the transarticular screws (TAS) group

	Preoperative	Postoperative	*P* value
ADI (mm.)	1.68 (1.3-6.75)	1.77 (1.36-1.91)	0.11
PADI (mm.)	15.44 (9.53-19.51)	17.18 (16.32-20.68)	0.208
NDAASC (mm.)	13.75 (8.86-16.09)	16.03 (15.5-19.2)	0.008
NCSS*	12 (12-12)	14 (13-14)	0.024
JOA score*			0.18
Grade 0 (16-17)	6	6	
Grade 1 (12-15)	0	1	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	1	0	

ADI: Atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.

*At 1 year of follow up

The SRC group shows statistically significant decrease ADI [1.62 (0.91-5.73) VS 1.08 (0.8-1.59), P = 0.001], while there was an increase for PADI [16.57 (12.56-20.07) VS 18.89 (15.92-20.96), P = 0.021], NDAASC had signi-ficantly widening spinal canal [12.8 (9.53-16.5) VS 15.75 (13.34-19.14), P < 0.001]. (Table 5)

Follow-up and outcome

There was a statistically significant result in postoperative JOA (P = 0.015) and postoperative NCSS at 1 year (P < 0.001) when compared with preoperative data. (Table 5)

Table 5 Preoperative and postoperative comparison of the screw-rod constructs (SRC) group

Preoperative	Postoperative	*P* value	
ADI (mm.)	1.62 (0.91-5.73)	1.08 (0.8-1.59)	0.001
PADI (mm.)	16.57 (12.56-20.07)	18.89 (15.92-20.96)	0.021
NDAASC (mm.)	12.8 (9.53-16.5)	15.75 (13.34-19.14)	< 0.001
NCSS*	12 (10-12)	14 (14-14)	< 0.001
JOA score*			0.015
Grade 0 (16-17)	16	22	
Grade 1 (12-15)	7	1	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	0	0	

ADI: Atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.
*At 1 year of follow-up

There were no statistically significant differences of baseline characteristic between translaminar C1 lateral mass screw fixation and sublaminar C1 lateral mass screw fixation (Table 6) and no statistically significant differences in ΔADI [0.46 (0-2.91) VS 0.02 (0-0.81), P = 0.454], ΔPADI [0.36 (-0.47-1.57) VS 0.05 (0-0.66), P = 0.947], ΔNDAASC [1.28 (0.24-3.92) VS 3.17 (0.35-5.63), P = 0.461], ΔNDAASC % [6.57 (1.67-30.77) VS 22.43 (1.56-62.98), P = 0.357] (Table 7).

Table 6 Patient baseline characteristics in sublaminar and translaminar C1 lateral mass screw technique

	Translaminar (10)	Sublaminar (19)	*P* value
Preoperative ADI (mm.)	1.975 (0.59-5.58)	1.57 (0.91-5.18)	0.89
Preoperative PADI (mm.)	15.825 (13.14-21.45)	18.58 (12.54-19.43)	0.748
Preoperative NDAASC (mm.)	14.14 (11.30-14.90)	11.11 (8.24-17.12)	0.359
Preoperative NCSS	12 (11-12)	12 (10-12)	0.12
Preoperative JOA score			0.519
Grade 0 (16-17)	7	11	
Grade 1 (12-15)	3	6	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	0	2	

ADI: Atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.
*Four patients in the SRC group did not have postoperative follow-up imaging.

Follow-up and outcome

One patient in the sublaminar C1 lateral mass screw fixation group had no fusion, he underwent an operation to revision and occipito-cervical fixation [10 (100%) VS 15 (93.8%), P = 1]. Postoperative clinical follow- up at 1 year in JOA (P = 0.381), NCSS (P = 0.858) and NCSS% (P = 0.953) showed no significant differences in both groups (Table 7).

Table 7 Postoperative outcome in Sublaminar and translaminar C1 lateral mass screw technique

	Translaminar (10)	Sublaminar (19)	*P* value
ΔADI (mm.)	0.46 (0-2.91)	0.02 (0-0.81)	0.454
ΔPADI (mm.)	0.36 (-0.47-1.57)	0.05 (0-0.66)	0.947
ΔNDAASC (mm.)	1.28 (0.24-3.92)	3.17 (0.35-5.63)	0.461
ΔNDAASC (%)	6.57 (1.67-30.77)	22.43 (1.56-62.98)	0.357
Fusion*	10 (100)	15 (93.8)	1
Postoperative NCSS 1 y**	14 (14-14)	14 (14-14)	0.858
Postoperative NCSS 1 y %**	100 (100-100)	100 (100-100)	0.953
Postoperative JOA score 1 y**			0.381
Grade 0 (16-17)	7	13	
Grade 1 (12-15)	1	0	
Grade 2 (8-11)	0	0	
Grade 3 (0-7)	0	0	

ADI: Atlanto-dental interval, PADI: posterior atlanto-dental interval, NDAASC: narrowest in A-P diameter of atlantoaxial spinal canal, NCSS: Neurosurgical cervical spine scale, JOA score: Japanese Orthopaedic Association score.

*Four patients in the sublaminar group were excluded due to not having postoperative follow-up imaging.

**Two patients in the translaminar group and 6 patients in the sublaminar group were excluded due to discontinuity of follow-up before 1 year.

Complication rates

There are very low complication rates, and no deaths and infection occurred in either group (Table 8). Only one patient in the SRC group treated with sublaminar C1 lateral mass screw technique was found with postoperative occipital neuralgia, and the symptom was improved after selective nerve root block (SNRB) Right C2 root 3 months after the surgery. Two patients in the SRC group with sublaminar C1 lateral mass screw technique were found with broken screws. One of the two patients was found with a broken screw one month after the surgery, the patient was given conservative treatment and significant fusion was found 9 months after the surgery. The other patient with Down's syndrome and os odontoideum, was found with a broken screw 9 months after the surgery due to a widening gap between odontoid and body of axis at post-operation and due to active movement of the neck after being discharged from the hospital. The patient then underwent an operation to he underwent an operation to revision and occipito-cervical fixation. Both patients did not show any signs of pain from the broken screws when returning for check-ups. (Table 9).

Table 8 Complication in the transarticular screws (TAS) and the screw-rod constructs (SRC) group

	TAS (9)	SRC (33)
Infection	0	0
Occipital neuralgia	0	1
Occipital numbness	0	0
Hardware failure	0	2

Table 9 Complication in translaminar and sublaminar C1 lateral mass screw groups

	Translaminar (10)	Sublaminar (19)
Infection	0	0
Occipital neuralgia	0	1
Occipital numbness	0	0
Hardware failure	0	2

Illustrative Cases

This patient was a 60-year-old female with a history of trauma and chronic neck pain. Imaging revealed evidence of C1-C2 instability with odontoid process fracture. She underwent C1-2 fixation by SRC technique (C1: sublaminar lateral mass screw technique, C2: translaminar screw fixation technique). Preoperative data showed ADI 1.02 mm, PADI 18.58 mm, NDAASC 8.24 mm, postoperative data showed ADI 1.02 mm, PADI 18.89 mm, NDAASC 13.43 mm. Preoperative and postoperative JOA scores were similar at 17. Preoperative and postoperative NCSS was 12 and 14, respectively. The NCSS improved at 100%. (Figure 9).

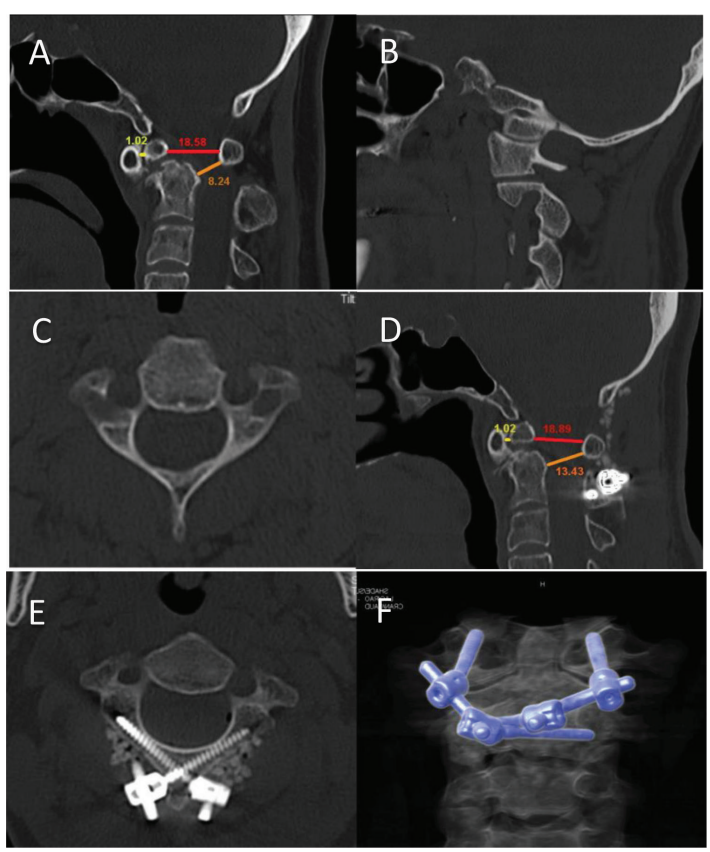


Figure 9 Illustrative Cases
Image showing that C1-2 spinal canal was narrow but PADI was not narrow and/or ADI is not wide.
(A): Image showing radiographic parameter in preoperative sagittal CT scan; ADI 1.02 mm. (yellow line), PADI 18.58 (red line), NDAASC 8.24 mm. (orange line) (B): Preoperative sagittal CT scan, high riding vertebral artery at C2, unsuitable for pars screw. (C) Preoperative axial CT scan, small bilateral C2 pedicle, its improper for pedicle screw. (D): Radiographic parameter in postoperative sagittal CT scan; ADI 1.02 mm. (yellow line), PADI 18.89 (red line), NDAASC 13.43 mm. (orange line) (E) Postoperative axial CT scan showing C2 laminar screws. (F) CT bone multiplanar reconstruction (MPR) showing C1 lateral mass screws with C2 lamina screws connected by rods.

Discussion

Transarticular screw technique as described by Magerl and Jeanneret in 1979, is a popular technique but its limitation is from high riding vertebral artery. C1–C2 screw fixation is used for C1–2 instability. Fusion using C1 lateral mass screw and C2 pedicle screw and plates is pioneered by Goel et al.[7] Later, Harms and Melcher[8] described C1 lateral mass screws connected to C2 pars or pedicle screw using rod. The modified technique for circumventing the limitation of anatomic variation such as C2 laminar screw, described by Wright and Leonard[9,10]. In a meta-analysis, Elliott et al.[11] reports a slightly higher rate of fusion with the SRC technique. In this study, C1–2 transarticular screw technique and C1–2 SRC technique were compared. The results of the two techniques did not show any statistically significant results in ΔADI, ΔPADI, ΔNDAASC, ΔNDAASC%, fusion rate, postoperative JOA at 1 year, postoperative NCSS at 1 year and postoperative NCSS% at 1 year. Both the TAS and the SRC technique showed significant outcomes in ADI, NDAASC, and NCSS, and a significant result in PADI and JOA was found in the SRC group when the preoperative and postoperative data were compared.

For the C1–2 screw fixation technique, the first method used was C2 nerve root resection but this method is often followed by occipital numbness complications. Modified technique for reducing this complication using C2 nerve root preservation technique but followed by occipital neuralgia complication. Elliott et al.[4] reported C2 nerve root section resulted in greater symptomatic numbness (11.6% VS 1.3%, $P < 0.0001$) but less neuropathic pain (0.3% VS 4.7%, $P = 0.0002$) compared with C2 preservation. The modified technique of sublaminar C1 lateral mass screw technique is developed to preserve C2 nerve root and used a long lag screw to prevent C2 nerve root irritation. Transarticular screw or posterior arch C1 lateral mass screw was technique used to prevent C2 nerve root irritation. In this study, C2 nerve root preservation technique was used in all patients and the analysis of sublaminar C1 lateral mass screw technique and translaminar C1 lateral mass screw technique in the SRC technique showed no significant differences and no incidence of postoperative occipital numbness between the two groups. Only one patient of sublaminar C1 lateral mass screw group using the SRC technique was found with occipital neuralgia (0.03%), which is less than the results found in previous studies.

Complication

In this study, the incidence of infection, vertebral artery injury, screw malposition, morbidity, and mortality were not found. One patient was found with occipital neuralgia of the GHLM technique. Her symptom occurred at postoperative and was slightly improved by medication, this symptom resolved after selective nerve root block (SNRB) at 3 months postoperation. Hardware failure occurred in 2 patients of the SRC group. The first of the two patients was a 62-year-old male who was found with a broken right C2 screw at 1 month after the surgery, after conservative management and follow-up, fusion of C1–2 was found at 10 months after the surgery. The other patient was a 7-year-old boy with Down's syndrome and os odontoideum who was found with a

broken right C1 screw at 9 months after the surgery, he underwent remove screw at C1 with occipital- C2 fixation. No neurologic symptom and neck pain at over time of follow up. In previous meta-analysis[11] comparing TAS and SRC technique, no significant difference was shown in 30 days mortality (0.8% VS 0.6%) or neurological injury (0.2% VS 0%). There was a high incidence of vertebral artery injury (4.1% VS 2.0%, $P = 0.02$) and malposition screws (7.1% VS 2.4%, $P < 0.001\%$).

Study limitation

Our study has several limitations, namely, a small number of cases were included in each group, the patients were not randomly assigned to each group, and the follow-up period was relatively short.

Conclusion

Both TAS and SRC techniques can be used for C1-2 instability because no statistically significant results were found in both groups and there was a low incidence of complication. Sublaminar and translaminar C1 lateral mass screw technique showed no statistically significant results. Sublaminar C1 lateral mass screw technique seems to yield a slightly higher rate of occipital neuralgia. The decision to use either technique of C1-2 fixation must be made after a careful review of the individual patient's anatomy on imaging and the surgeon's experiences.

References

1. Mummaneni PV, Haid RW. Atlantoaxial fixation Overview of all techniques. Neurol India. 2005;53(4):408-15.
2. Moisi M, Fisahn C, Tkachenko L, Jeyamohan S, Reintjes S, Grunert P, et al. Posterior arch C-1 screw technique: a cadaveric comparison study. J Neurosurg Spine. 2017; 26(6):679-83.
3. Yamagata T, Takami T, Naito K, Ohata K. C2 nerve root resection to achieve safe and wide exposure of lateral atlantoaxial joints in posterior C1-2 instrumented fixation: technical note. Neurol Med Chir (Tokyo). 2013;53(12):914-9.
4. Elliott RE, Kang MM, Smith ML, Frempong-Boadu A. C2 Nerve Root Sectioning in Posterior Atlantoaxial Instrumented Fusions: A Structured Review of Literature. World Neurosurgery. 2012:78(6):697-708.
5. Lin JM, Hipp JA, Reitman CA. C1 lateral mass screw placement via the posterior arch: a technique comparison and anatomic analysis. Spine J. 2013;13(11):1549-55.
6. Lee SH, Kim ES, Eoh W. Modified C1 lateral mass screw insertion using a high entry point to avoid postoperative occipital neuralgia. J Clin Neurosci. 2013; 20(1):162-7.
7. Ma W, Feng L, Xu R, Liu X, Lee AH, Sun S, et al. Clinical application of C2 laminar screw technique. Eur Spine J. 2010;19(8):1312-7.
8. Harms J, Melcher RP. Posterior C1-C2 Fusion with Polyaxial Screw and Rod Fixation. Spine (Phila Pa 1976). 2001;26(22):2467-71.
9. Wright NM. Posterior C2 fixation using bilateral, crossing C2 laminar screws: case series and technical note. J Spinal Disord Tech. 2004;17(2):158-62.
10. Wright NM. Translaminar rigid screw fixation of the axis. Technical note. J Neurosurg Spine. 2005;3(5): 409-14.
11. Elliott RE, Tanweer O, Akwasi B, Morsi A, Ma TS, Frempong-Boadu A, et al. Outcome Comparison of Atlantoaxial Fusion with Transarticular Screws and Screw-Rod Constructs: Meta-Analysis and Review of Literature. Clinical Spine Surgery: 2014;27(1):11-28.