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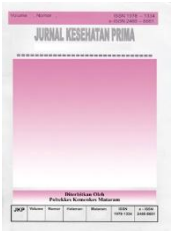

Urine Output as a Non-Invasive Marker of Intracranial Pressure Changes After Furosemide in Craniotomy Patients

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Abstract

Craniotomy is a common surgical procedure in the neurosurgery division that involves making a sufficient hole in the cranium for optimal intracranial access. An important part of craniotomy is the maintenance of stable intracranial pressure by administering furosemide. The purpose of this administration is to observe changes in urine output. The sampling technique used total sampling with a total of 31 respondents. Data were analyzed using Fisher's exact test. The results of this study showed that most patients experienced changes in urine output volume of 27 respondents (87.1%) with an average change in urine from 245.8 ml to 1469.3 ml. There is a statistically significant relationship between furosemide administration and changes in urine output volume of craniotomy patients with the fisher exact test obtained a value of $\rho = 0.013$, so that alternative hypothesis can be accepted. The Conclusion there is a relationship between furosemide administration and changes in urine output volume of craniotomy patients at hospital in Tegal City.

Keywords: Furosemide; Urine Output Volume; Intracranial Pressure; Craniotomy

INTRODUCTION

The problem of head injury can occur due to sudden falls, vehicle accidents, sharp and blunt object collisions, dynamic and static object collisions (Manurung, 2018). A study in 2006 showed that head injuries and wounds ranked sixth out of the total hospitalized cases in Indonesia. The highest prevalence was found in South Sulawesi at 12.8%, the lowest in Jambi at 4.5%, while in Central Java province, 7.7% of injuries were caused by motorcycle accidents (40.1%). Most of the injuries were suffered by adults (38.8%), elderly (13.3%) and children (11.3%) (Riskesdas, 2018).

Some complications of head injuries include increased intracranial pressure (ICP), subdural effusion, hydrocephalus, bleeding to hypovolemic shock, pain, ineffective breathing patterns, risk of ineffective brain perfusion, ineffective airway, acute pain, anxiety, infection, and seizures, which can lead to death (Kinanti and Siwi, 2022).

In cases of severe head injury complications, surgical intervention such as

craniotomy may be required. Craniotomy is a common surgical procedure in neurosurgery, where a sufficient hole is made in the skull to create optimal intracranial access (Valentino et al., 2019).

According to Gracia (2017), the only anesthesia method used for craniotomy procedures today is neuroanesthesia. The main goals of neuroanesthesia are to facilitate surgery, control intracranial pressure and brain volume, protect neural tissue from injury and ischemia (protect the brain), and reduce bleeding during surgery. One way to reduce intracranial pressure during the duration of craniotomy surgery is by administering furosemide. Furosemide acts on intracranial pressure (ICP) by gradually relieving general cerebral symptoms, reducing cerebral edema through increased intracellular water transport, and concomitant periods of decreased pressure and cerebrospinal fluid formation. The magnitude of this decrease is associated with furosemide-induced increases in chloride and sodium-containing urinary secretions (Sidhapramudita Mangastuti et al, 2018).

This increase in urinary secretion is of course closely related to changes in the volume of urine output, which is characterized by one of the signs of increased ICP, namely oliguria and then normal urine. This result then also indicates the process of urine formation which was initially abnormal to normal which is related to one of the anesthesiologist's authority, namely monitoring the intraoperative fluid balance to be able to get the results of changes in the volume of intraoperative urine output. In the Central Surgical Installation of RSUD Kardinah Kota Tegal, furosemide was given as an effort to reduce intracranial pressure by 6 ampoules or the equivalent of 120 mg/12 ml (1 ampoule = 20mg/2 ml). However, until now there has been no study that observed changes in urine output volume in craniotomy patients after furosemide administration, especially in Tegal City hospital. Therefore, this condition needs to be resolved through a study that aims to see changes in urine output volume after furosemide administration. Steps taken were monitoring the results of urine volume output during intraoperative to show the number of changes in urine output volume as one of the manifestations of decreased intracranial pressure.

METHOD

This study was an observational analytic quantitative method with cross sectional design. The population in this study were all patients who underwent craniotomy in the central surgical installation of hospitals in Tegal City from February 12 to March 23, 2024. The sample was determined by total sampling technique of 31 respondents based on the criteria: patients willing to be respondents, respondents who were scheduled for elective craniotomy surgery or emergency craniotomy with general anesthesia techniques. patients with ASA I - IV, and patients aged 17 - 65 years.

This study used instruments in the form of observation sheets, urometers, fluid intake and output charts consisting of name, medical record

number, diagnosis, furosemide dose, fluid in, fluid out, and amount of urine. Data analysis using the fisher excat test (X2) at the p<0.05 level of significance. Research ethical feasibility test at KEPK Poltekkes Kemenkes Yogyakarta with ethical feasibility letter No.DP.04.03/e-KEPK.1/118/2024.

RESULT AND DISCUSSION

Table 1. Frequency Distribution of Respondent Characteristics Based on Age and ASA

Characteristics	f	(%)
Age		
Late adolescence (17 - 25 years)	4	12,9
Early adulthood (26 - 35 years)	2	6,5
Late adulthood (36 - 45 years)	6	19,4
Early old age (46 - 55 years)	14	45,2
Late old age (56 - 65 years)	5	16
ASA		
ASA I	4	12,9
ASA II	13	41,9
ASA III	10	32,3
ASA III E	1	3,2
ASA IV	3	9,7
Total	31	100

Table 1 shows the frequency distribution of the characteristics of respondents consisting of age and ASA of respondents with a total of 31 respondents showing that the majority of ages that dominate are respondents aged 46-55 years, namely the age category of early adulthood with 14 respondents (45.2%), while the least in the characteristics of respondents are respondents aged 26-35 years, namely the early adulthood age category with 2 respondents (6.5%). Furthermore, in ASA physical status, the majority of respondents who dominated had ASA II physical status with 13 respondents (41.9%), while the least ASA physical status in the characteristics of respondents was respondents with ASA III E physical status, namely 1 respondent (3.2%).

a. Frequency Distribution of Furosemide Dose Use and Changes in Urine Output Volume of Hospitals in Tegal City

Table 2. Frequency Distribution of Furosemide Dose Use and Changes in Urine Output Volume

Furosemide Drug Dosage Amount	f	(%)
Furosemide at the correct dose (120 mg)	29	93,5
Furosemide inappropriate dose (< 120 or > 120 mg)	2	6,5
Total	**31**	**100**
Changes in Urine Output Volume	**f**	**(%)**
Changes in Urine Output Volume	27	87,1
Fixed Urine Output Volume	4	12,9
Total	**31**	**100**

Table 2 shows the administration of furosemide with a total sample of 31 respondents, respondents with the appropriate dose (120 mg) were 29 respondents (93.5%) and respondents with furosemide administration not in accordance with the dose (< 120 mg or > 120 mg) were 2 respondents (6.5%). The data showed that respondents with furosemide administration according to the dose (120 mg) were more than respondents with inappropriate furosemide administration (< 120 mg or > 120 mg). Then the number of respondents with changes in urine output volume was 27 respondents (87.1%) and respondents with fixed urine output volume were 4 respondents (12.9%). The data showed that respondents who experienced changes in urine output volume were more than respondents who experienced a fixed urine output volume.

Respondents who underwent craniotomy surgical procedures at Kardinah Hospital, Tegal City on February 12-March 23, 2024, with a total of 31 respondents. This study used 2 kinds of doses of furosemide drug use, namely with a dose of less than 120 mg and most with a dose of 120 mg. The data obtained, namely, the administration of furosemide is not in accordance with the dose (< 120 mg) which is in a small part with the age category of the early elderly (46-65 years) who have ASA II then obtained primary data from the results of interviews that respondents have a body weight < 50 kg.

This is in accordance with Khaliq's research (2020), namely ASA can have an effect on causing the response of certain organs to the absorption of drugs given intraoperatively. In addition, in the research of Gerontrol, et al. (2021) in the elderly, drug dosing must pay attention to factors such as changes in distribution volume, changes in protein binding, metabolic disorders, and impaired renal excretion.

The variation of changes in the elderly is influenced by individual factors, namely smoking and nutritional factors (related to nutrition and body weight). Furthermore, this is in line with research conducted by Andrea Tham (2022), namely the dose of furosemide administration at the age of ≥ 17 years with a body weight ≥ 50 kg in several cases, namely: edema cases of 20-80 mg of drug administration once a day, can be increased by 20-40 mg every 6-8 hours, not exceeding 600 mg / day, hypertension cases of 20-80 mg of drug administration divided every 12 hours, cases of acute pulmonary edema or hypertensive crisis or increased intracranial pressure of 40 mg IV for 1-2 minutes then increased by an additional 80 mg, with a maximum dose when it has not worked for 1 hour, namely 160-200 mg / dose.

The action of furosemide on intracranial pressure is due to a decrease in central venous pressure, an increase in venous blood flow from the cranial cavity, as well as a decrease in its volume. Furosemide can effectively lower ICP in various clinical conditions examining the relationship between dose and magnitude of ICP reduction. Changes in cerebrospinal fluid formation with furosemide were measured

within the dose range shown to reduce ICP, namely at the age of ≥ 17 years as much as 120 mg. The results of this study are in line with the research of Khan et al. (2023), namely one case of the incidence of patients with intracranial hypertension of tumor origin, furosemide administration caused general cerebral symptoms to subside gradually, along with a period of decreased cerebrospinal fluid pressure. The magnitude of this decrease is attributed to furosemide-induced increased secretion of chlorine- and sodium-containing urine. Decrease in cerebrospinal fluid pressure or change in intensity of general cerebral symptoms and reduction of cerebral edema through increased cellular water transport.

Table 3. Frequency Distribution of Mean Changes in Urine Output Volume Pre and Post Furosemide Administration

***Output* Urine**	**Volume *Output* Urine**				***Mean***
	Oliguria		**Normal**		
	f	**%**	**f**	**%**	
Pre Furosemide Administration	29	93,5	2	6,5	245,8
Post Furosemide Administration	4	12,9	27	87,1	1469,3

Table 3 shows the urine output rate at pre administration of furosemide with a total sample of 31 respondents, 29 respondents with oliguria urine volume (93.5%) and 2 respondents with normal urine volume (6.5%) with an average urine pre administration of furosemide as much as 245.8 ml (Oliguria). While the number of urine output in post furosemide administration with oliguria urine volume was 4 respondents (12.9%) and respondents with normal urine volume were 27 respondents (87.1%) with an average urine post furosemide administration of 1469.3 ml (Normal). In the acquisition of these data shows that the average urine volume pre administration of furosemide is oliguria category while the average urine volume post administration of furosemide is normal category.

Respondents who underwent craniotomy surgical procedures at Kardinah Hospital, Tegal City on February 12-March 23, 2024, namely a total of 31 respondents with a small proportion experiencing a fixed volume of urine output as a manifestation of intracranial pressure as seen from one of the clinical signs that oliguria still occurs and from the observation of anesthesiologists and neurosurgeons, while most respondents experienced changes in urine output volume as a manifestation of decreased intracranial pressure as seen from one of the clinical signs of normal urine production and fluid balance and from the observation of anesthesiologists and neurosurgeons. The results of this study are in line with Gracia (2017), the main objectives of neuroanesthesia are to facilitate surgery, control intracranial pressure

and brain volume, protect nerve tissue from injury and ischemia (protect the brain), and reduce bleeding during surgery.

Changes in urine output volume can be seen from one of the clinical signs, namely urine production, this is recorded and seen on the intraoperative fluid intake and output chart which is in line with the research of Anggraini et al. (2016). Then also in the research of J Bell et al, 2014 with the results of the intake and output chart on diuretic administration, namely p value = 0.01 or with acceptable accuracy in the alternative hypothesis. This shows that when the respondent's urine production is oliguria and an abnormal fluid balance is obtained (< 200 ml or > 400 ml) it is concluded that intracranial pressure remains, but when urine production is normal and fluid balance is normal (200-400 ml) it can be concluded that there is a change in urine output volume. As for the data obtained, overall respondents who experienced fixed intracranial pressure were at an early elderly age (46-55 years) and in ASA II and III where oliguria still occurs as one of the clinical signs of fixed intracranial pressure.

In the research of Mayhew et al. (2019), namely ASA is a tool at the time of preoperative which can clarify or predict the difficulty of both surgery or anesthesia during intraoperative and postoperative. This analysis concluded that the higher the ASA, the more complications that arise. This is also related to the clinical and age of the respondents, then this is in accordance with the research of Sulaiman, et al. (2020), namely in the elderly, especially men, there is an enlarged prostate that can clamp the urinary tract and neurological disorders, while in elderly women it is caused by a decrease in bladder muscle work due to parity, number of pregnancies, history of birth methods, and history of hysterectomy surgery.

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Relationship between Furosemide Administration and Changes in Urine Output Volume of Caranitomy Patients

Table 4. Relationship between Furosemide Administration and Changes in Urine Output Volume

Furosemide Dosage	**Urine Output Volume**				***p-value* (*Fishers Exact Test*)**
	Changes in Urine Output Volume		**Fixed Urine Output Volume**		
	f	**%**	**f**	**%**	
Furosemide at the correct dose (120 mg)	27	87,2	2	6,4	0,013
Furosemide inappropriate dose (< 120 or > 120 mg)	0	0	2	6,4	

Table 4 shows that 27 respondents (87.2%) were given the appropriate dose of furosemide (120 mg) with changes in urine output volume, 2 respondents (6.4%) were given the appropriate dose of furosemide (120 mg) with fixed urine

output volume, and 2 respondents (6.4%) were given the inappropriate dose of furosemide (< 120 mg or > 120 mg) with fixed urine output volume. The results of statistical tests with the alternative fishers exact test showed that the resulting p-value was 0.013 (p-value <0.05) which showed that there was a relationship between furosemide administration on changes in urine output volume of craniotomy respondents at Kardinah Hospital, Tegal City, thus it can be interpreted that the alternative hypothesis is accepted and the null hypothesis is rejected.

Based on research conducted on respondents who underwent craniotomy surgical procedures at the Kardinah Hospital, Tegal City on February 12-March 23, 2024, namely a total of 31 respondents with a small proportion experiencing urine output volume as one of the manifestations of fixed ICT as seen from one of the clinical signs that oliguria still occurs and from the observation of anesthesiologists and neurosurgeons, while most respondents experienced changes in urine output volume as seen from one of the clinical signs of normal urine production and normal fluid balance and from the observation of anesthesiologists and neurosurgeons.

The results of statistical tests with the alternative fishers exact test showed that the resulting p-value was 0.013 (p-value <0.05) which showed that there was a relationship between furosemide administration on changes in urine output volume in Tegal City Hospital, thus it can be interpreted that Ha is accepted and Ho is rejected. The results of this study are in line with research by Amri (2017) which states that one of the clinical monitoring of intracranial pressure can be observed from the volume of urine output which when the volume of urine output remains oliguria indicates that intracranial pressure remains as a sign of a cushing trias reflex, whereas when the volume of urine output becomes normal it indicates a change in the volume of urine output as a manifestation of decreased intracranial pressure in respondents.

The data related to respondents who did not get furosemide according to the dose (< 120 mg) then there was no change in urine output volume due to not using the gold standard dose of 120 mg due to lack of body weight (< 50 kg) so that it could not meet the dose of use, this is in accordance with the research of Andrea Tham (2022) also explained that there is a dose of furosemide administration at the age of ≥ 17 years with a body weight ≥ 50 kg in several cases, namely: edema cases of 20-80 mg of drug administration once a day, can be increased by 20-40 mg every 6-8 hours, not exceeding 600 mg / day, hypertension cases of 20-80 mg of drug administration divided every 12 hours, cases of acute pulmonary edema or hypertensive crisis or increased intracranial pressure of 40 mg IV for 1-2 minutes then increased by 80 mg increments, with a maximum dose when it has not worked for 1 hour, namely 160-200 mg / dose. This illustrates that this study is relevant to the study, namely the relationship between the administration of furosemide at a dose of 120 mg at the age of ≥ 17

years with a body weight ≥ 50 kg with changes in urine output volume as seen from one of the clinical signs, namely the production of urine output volume from oliguria to normal.

Second, the data of respondents who have received furosemide according to the dose (120 mg) but experienced a fixed volume of urine output, this occurred in the early elderly age range of 46-55 years and in ASA III. This can be caused by other factors, namely the existence of age factors in accordance with the research of Sulaiman, et al. (2020), namely in the elderly, especially men, there is an enlarged prostate that can clamp the urinary tract and neurological disorders, while in elderly women it is caused by a decrease in bladder muscle work due to parity, number of pregnancies, history of birth methods, and history of hysterectomy surgery. Of course, the above can cause oliguria to continue due to poor urinary tract and bladder function, furthermore, this age factor is also supported by the research of Amalya, et al. (2023), namely at the time of old age the regeneration ability of nephrons has been reduced and cannot even perform generation anymore, so that kidney function decreases with age, starting from the age of 40 years there is a decrease of ± 8 ml / min / 1.73 m^2 every decade. Next is the ASA factor, this is in accordance with Khaliq's research (2020), namely ASA can have an effect on causing the response of certain organs to the absorption of drugs given intraoperatively, then also supported by research by Mayhew et al. (2019), namely ASA is a tool at the time of preoperative that can clarify or predict the difficulty of both surgery or anesthesia during intraoperative and postoperative. This analysis concluded that the higher the ASA, the more complications that arise. The two things above are certainly interrelated even though furosemide has been given according to the dose of 120 mg but there is still no change in the volume of urine output due to several factors, namely the elderly age factor which causes organ function to no longer be optimal and also the ASA physical status which is high enough to make drug absorption less effective and more at risk of complications.

The three respondent data who received the appropriate dose of 120 mg and experienced changes in urine output volume were seen from the volume of urine output that had used the gold standard according to Andrea Tham's research (2022), namely using 40 mg of furosemide and then adding 80 mg so that it became 120 mg to reduce intracranial pressure which could later be seen from the normal volume of urine output. This is also in line with the research of Sidhapramudita Mangastuti et al (2018), namely with efforts to reduce intracranial pressure by administering furosemide. Furosemide works on intracranial pressure (ICP) by gradually relieving general cerebral symptoms, reducing cerebral edema through increased intracellular water transport, and along with a period of decreased pressure and cerebrospinal fluid formation. The magnitude of this decrease is associated with furosemide-induced increases in the secretion of chlorine- and sodium-containing urine. This increase in urinary secretion is of course closely related to changes in the volume of urine output, which is characterized

by a sign of increased ICP, namely oliguria, which then becomes normal urine. This result then also indicates the process of urine formation which was initially abnormal to normal which is related to monitoring the intraoperative fluid balance to be able to get the results of changes in urine output volume as one of the manifestations of ICP reduction through urine output volume.

The limitation of this research were the characteristics of respondents in this study were dominated by the early elderly age category (46-55 years) and the majority of ASA II physical status. Statistical test results with ρ-value 0.013 (ρ <0.05). From the results of research and statistical tests conducted by researchers, it can be concluded that there is a relationship between furosemide administration on changes in urine output volume in Tegal City hospital.

CONCLUSION

There is a statistically significant relationship between furosemide administration and changes in urine output volume of craniotomy patients with the fisher exact test obtained a value of ρ = 0.013, so that alternative hypothesis can be accepted. The Conclusion there is a relationship between furosemide administration and changes in urine output volume of craniotomy patients at hospital in Tegal City..

REFERENCES

Alanazi, A. H., Adil, M. S., Lin, X., Chastain, D. B., Henao-Martínez, A. F., Franco-Paredes, C., & Somanath, P. R. (2022). Elevated Intracranial Pressure in Cryptococcal Meningoencephalitis: Examining Old, New, and Promising Drug Therapies. *Pathogens*, *11*(7), 783. https://doi.org/10.3390/pathogens11070783

Alshammari, S., Alyahya, M. A., Allhidan, R. S., Assiry, G. A., AlMuzini, H. R., & AlSalman, M. A. (2020). Effect of Urinary Incontinence on the Quality of Life of Older Adults in Riyadh: Medical and Sociocultural Perspectives. *Cureus*. https://doi.org/10.7759/cureus.11599

Amri, I. (2017). *PENGELOLAAN PENINGKATAN TEKANAN INTRAKRANIAL*. *4*(3).

Boles Ponto, L. L., & Schoenwald, R. D. (1990). Furosemide (Frusemide): A Pharmacokinetic/Pharmacodynamic Review (Part II). *Clinical Pharmacokinetics*, *18*(6), 460–471. https://doi.org/10.2165/00003088-199018060-00003

Carone, L., Oxberry, S. G., Twycross, R., Charlesworth, S., Mihalyo, M., & Wilcock, A. (2016). Furosemide. *Journal of Pain and Symptom Management*, *52*(1), 144–150. https://doi.org/10.1016/j.jpainsymman.2016.05.004

Daabiss, M. (2011). American Society of Anaesthesiologists physical status classification. *Indian Journal of Anaesthesia*, *55*(2), 111. https://doi.org/10.4103/0019-5049.79879

Departemen Anestesiologi & Terapi Intensif Rumah Sakit Mayapada Lebak Bulus, Jakarta Selatan, Sidhapramudita Mangastuti, R., Umar, N., Departemen Anestesiologi & Terapi Intensif Fakultas Kedokteran Universitas Sumatera Utara–RSUP H. Adam Malik Medan, Rasman,

M., & Departemen Anestesiologi &Terapi Intensif–Fakultas Kedokteran Universitas Padjadjaran– RSUP Dr. Hasan Sadikin Bandung. (2015). Total Intravenous Anesthesia pada Geriatri dengan Meningioma Parietalis. *Jurnal Neuroanestesi Indonesia*, *4*(2), 112–118. https://doi.org/10.24244/jni.vol4no2.90

Department of Anesthesiology and Intensive Care Dr. Hasan Sadikin General Hospital Faculty of Medicine Universitas Padjadjaran Bandung, Monica Rahardo, T., Fuadi, I., Bisri, T., & Department of Anesthesiology and Intensive Care Dr. Hasan Sadikin General Hospital Faculty of Medicine Universitas Padjadjaran Bandung. (2012a). Penatalaksanaan Anestesia pada Pasien Cretin dengan Hipopituitarisme Sekunder Akibat Kraniofaringioma. *Jurnal Neuroanestesi Indonesia*, *1*(3), 197–202. https://doi.org/10.24244/jni.vol1i3.177

Department of Anesthesiology and Intensive Care Dr. Hasan Sadikin General Hospital Faculty of Medicine Universitas Padjadjaran Bandung, Monica Rahardo, T., Fuadi, I., Bisri, T., & Department of Anesthesiology and Intensive Care Dr. Hasan Sadikin General Hospital Faculty of Medicine Universitas Padjadjaran Bandung. (2012b). Penatalaksanaan Anestesia pada Pasien Cretin dengan Hipopituitarisme Sekunder Akibat Kraniofaringioma. *Jurnal Neuroanestesi Indonesia*, *1*(3), 197–202. https://doi.org/10.24244/jni.vol1i3.177

Department of Anesthesiology and Neurology Henan Provincial People's Hospital Zhengzhou China, Sepviyanti Sumardi, F., Hamzah, H., Department of Anesthesiology and Intensive Care Dr. Soetomo General Hospital Faculty of Medicine Universitas Airlangga, Rahardjo, S., Department of Anesthesiology and Intensive Care Dr. Sardjito General Hospital Faculty of Medicine Universitas Gadjah Mada Yogyakarta, Bisri, T., & Department of Anesthesiology and Intensive Care Dr. Hasan Sadikin General Hospital Faculty of Medicine Universitas Padjadjaran Bandung. (2018). Tatalaksana Kraniektomi Dekompresif pada Pasien Cedera Otak Traumatik Berat yang Disertai Peningkatan Tekanan Tinggi Intrakranial Menetap. *Jurnal Neuroanestesi Indonesia*, *7*(3), 185–197. https://doi.org/10.24244/jni.vol7i3.19

Dermawaty, D. E., & Oktaria, D. (n.d.). *Hematom Intraventrikular Disertai Hidrosefalus Obstruktif*.

Eftekhari, S., Westgate, C. S. J., Uldall, M. S., & Jensen, R. H. (2019). Preclinical update on regulation of intracranial pressure in relation to idiopathic intracranial hypertension. *Fluids and Barriers of the CNS*, *16*(1), 35. https://doi.org/10.1186/s12987-019-0155-4

Fakultas Ilmu Keperawatan Universitas Indonesia, Jakarta - Indonesia, Angraini, F., Putri, A. F., & Fakultas Ilmu Keperawatan Universitas Indonesia, Jakarta - Indonesia. (2016). Pemantauan Intake Output Cairan pada Pasien Gagal Ginjal Kronik dapat Mencegah Overload Cairan. *Jurnal Keperawatan Indonesia*, *19*(3), 152–160. https://doi.org/10.7454/jki.v19i3.475

Finkbeiner, A. E. (1993). The aging bladder. *International Urogynecology Journal*, *4*(3), 168–174. https://doi.org/10.1007/BF00571628

Fuadi, I., Pison, O. M., & Redjeki, I. S. (2015). Penatalaksanaan Cairan pada Pasien Pediatrik yang Menjalani Kraniotomi.

Critical Care, *33*(1).

Kartikasari, F. D., & Herianto, A. (n.d.). *PENERAPAN TINDAKAN HEAD UP 30° UNTUK MENINGKATKAN PERFUSI SEREBRAL PADA PASIEN POST CRANIOTOMY DI RUANG ICU RSST KLATEN*.

Kim, H. S., Lee, J. Y., Jung, J. W., Lee, K. H., Kim, M. J., & Park, S.-B. (2021). Is mannitol combined with furosemide a new treatment for refractory lymphedema? A case report. *World Journal of Clinical Cases*, *9*(29).

Li, G., Chen, Y., Hu, H., Liu, L., Hu, X., Wang, J., Shi, W., & Yin, D. (2012). Association Between Age-Related Decline of Kidney Function and Plasma Malondialdehyde. *Rejuvenation Research*, *15*(3), 257–264. https://doi.org/10.1089/rej.2011.1259

Li, L. (2015). Efficacy and Safety of Continuous Micro-Pump Infusion of 3% Hypertonic Saline combined with Furosemide to Control Elevated Intracranial Pressure. *Medical Science Monitor*, *21*, 1752–1758. https://doi.org/10.12659/MSM.892924

Lorenzo, A., Hornig, G., Zavala, L., Boss, V., & Welch, K. (1986). Furosemide Lowers Intracranial Pressure by Inhibiting CSF Production. *European Journal of Pediatric Surgery*, *41*(S 1), 10–12. https://doi.org/10.1055/s-2008-1043386

Mangastuti, R. S., Umar, N., & Rasman, M. (n.d.). *Total Intravenous Anesthesia pada Geriatri dengan Meningioma Parietalis*.

Mangastuti, R. S., Wargahadibrata, H., & Umar, N. (n.d.). *Penatalaksanaan Anestesi dengan TIVA Propofol-Dexmedetomidine-Fentanyl untuk Operasi Meningioma Frontalis Sinistra*.

McGeown, M. G. (1983). Fluid balance records and their interpretation. In M. G. McGeown, *Clinical Management of Electrolyte Disorders* (pp. 44–50). Springer Netherlands. https://doi.org/10.1007/978-94-009-6699-4_6

POlito, B., & Schoenwald, R. D. (n.d.). *A Pharm aco kin etic/ Pharm acodynamic Rc\'ic" (Part 1)*.

Pollay, M., Roberts, P. A., Hisey, B., Pendleton, B., Koontz, D., Smith, R., & Stevens, F. A. (1986). The Effect of Furosemide on Intracranial Pressure and Cerebrospinal Fluid Formation. In J. D. Miller, G. M. Teasdale, J. O. Rowan, S. L. Galbraith, & A. D. Mendelow (Eds.), *Intracranial Pressure VI* (pp. 597–600). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-70971-5_113

Roberts, P. A., Pollay, M., Engles, C., Pendleton, B., Reynolds, E., & Stevens, F. A. (1987). Effect on intracranial pressure of furosemide combined with varying doses and administration rates of mannitol. *Journal of Neurosurgery*, *66*(3), 440–446. https://doi.org/10.3171/jns.1987.66.3.0440

RSIA St. Carolus Sumarecon Serpong Tangerang, S. Mangastuti, R., J. Oetoro, B., Departemen Anestesiologi & Terapi Intensif Rumah Sakit Mayapada Tangerang, Sudadi, & Departemen Anestesiologi & Terapi Intensif Fakultas Kedokteran Universitas Gadjah Mada–RSUP. Dr. Sardjito Yogyakarta. (2014). Penatalaksanaan Anestesi pada Pasien Stroke Hemoragik. *Jurnal Neuroanestesi Indonesia*, *4*(2), 80–87. https://doi.org/10.24244/jni.vol3no2.61

Salsabila, A., Herman, H., Shafira, N. N. A., Fauzan, R., & Wulandari, P. S. (2023).

Gambaran Karakteristik Gagal Ginjal Kronik Obstruktif dan Non-obstruktif pada Pasien Dewasa-Lansia di RSUD Raden Mattaher Tahun 2017-2020. *Journal of Medical Studies*, *3*(2), 85–94. https://doi.org/10.22437/joms.v3i2.27367

Tanriono, C., Laleno, D. C., & Laihad, M. L. (2017). Profil Pasien Pasca Kraniotomi di ICU RSUP Prof. Dr. R. D. Kandou Manado Periode Juli 2016—Juni 2017. *E-CliniC*, *5*(2). https://doi.org/10.35790/ecl.5.2.2017.18541

Thenuwara, K., Todd, M. M., & Brian, J. E. (2002). Effect of Mannitol and Furosemide on Plasma Osmolality and Brain Water. *Anesthesiology*, *96*(2), 416–421. https://doi.org/10.1097/00000542-200202000-00029

Todd, M. M., Cutkomp, J., & Brian, J. E. (2006). Influence of Mannitol and Furosemide, Alone and in Combination, on Brain Water Content after Fluid Percussion Injury. *Anesthesiology*, *105*(6), 1176–1181. https://doi.org/10.1097/00000542-200612000-00017

Umam, K., & Susanto, J. (2020). Gambaran Aktivitas Perawat tentang Penatalaksanaan Masalah Pk: Peningkatan Tekanan Intrakranial. *Jurnal Kesehatan Vokasional*, *4*(4), 176. https://doi.org/10.22146/jkesvo.50314

Wang, L. C., Papangelou, A., Lin, C., & Mirski, M. A. (n.d.). *Perbandingan Equivolume, Solusi Equiosmolar Mannitol dan Saline Hipertonik dengan atau tanpa Furosemid pada Kadar Air Otak pada Tikus Normal*.

Wullur, C., & Bisri, D. Y. (n.d.). *Penatalaksanaan Anestesi pada Pasien dengan Tumor Supratentorial Berukuran Besar Suspek Konveksitas Meningioma*.

Yusuf Hisam, Sudadi, & Sri Rahardjo. (2023). Tatalaksana Peningkatan Tekanan Intra Kranial (TIK) pada Operasi Craniotomi Evakuasi Hematom yang disebabkan oleh Hematom Intracerebral. *Jurnal Komplikasi Anestesi*, *1*(1), 35–42. https://doi.org/10.22146/jka.v1i1.5525

Zheng, H., Chen, C., Zhang, J., & Hu, Z. (2016). Mechanism and Therapy of Brain Edema after Intracerebral Hemorrhage. *Cerebrovascular Diseases*, *42*(3–4), 155–169. https://doi.org/10.1159/000445170