Geometric accuracy on verification of stereotactic radiotherapy with the use of a double mask versus the Leksell G frame

T Kurjana¹, S Gondhowiardjo²* and R A Aman³

¹Department of Radiotherapy, Faculty of Medicine, Universitas Indonesia, Jakarta, 10430, Indonesia
²Radiation Oncology Residency Program, Faculty of Medicine, Universitas Indonesia, Jakarta, 10430, Indonesia
³Department of Neurosurgery, Faculty of Medicine, Universitas Indonesia, Jakarta, 10430, Indonesia

*E-mail: gondhow@gmail.com

Abstract. Patient immobilization is an important element for the geometric accuracy of stereotactic radiotherapy (SRT) techniques. However, differences in the immobilization and accuracy with the use of a G frame versus a double remain unknown. The aim of this retrospective comparative cross-sectional study was to compare the extents of geometrical shifting on verification of stereotactic techniques with the use of a G frame versus a double mask. The study cohort included patients who received RT between February and March 2016 at the Department of Radiotherapy of Cipto Mangunkusumo Hospital. The t-test was used to compare geometrical shifting values on verification with the use of a G frame versus a double mask. The mean value of geometrical shifting in patients with SRT with the use of a double mask on the laterolateral, craniocaudal, and anteroposterior axes were 0.4 ± 0.3, 0.5 ± 0.4, and 0.5 ± 0.4 mm, respectively, while values with the use of a G frame were 0.3 ± 0.2, 0.3 ± 0.4, and 0.4 ± 0.3 mm, respectively. There were no differences in the mean geometrical shifting values with the use of a double mask versus a G frame.

1. Introduction
Radiotherapy (RT) involves the precise delivery of a measured dose of ionizing radiation to the volume of the tumor with minimal damage to the surrounding normal tissue [1]. The role of RT has increased rapidly over the last few years as a result of the growing indications in the field of imaging, particularly for brain tumors that are often located around organs at risk. Accurate positioning and immobilization are required to deliver ionizing radiation to the tumor while maintaining the functions of neighboring organs.

Stereotactic RT (SRT) is a three-dimensional (3D) radiation technique that was developed for the accurate delivery of radiation to tumors of the brain, lung, and abdomen [2,3]. This technique has the potential to eradicate tumors by providing high doses of radiation along with a high degree of accuracy.
in accordance with the shape and contour of the tumor, by appropriately increasing the dose of radiation to the tumor, while minimizing the dose to normal tissues adjacent to the tumor [4].

At present, stereotactic radiosurgery (SRS) and SRT are the most widely used stereotactic radiation techniques for the treatment of brain tumors. Brain tumors account for 85%–90% of all central nervous system tumors with an incidence of 6.6 cases and 4.7 deaths per 100,000 population in the US. However, the epidemiological data of brain tumors in Indonesia remain inadequate [5].

SRS or SRT requires accurate immobilization of the patient, especially those with brain tumors, to ensure geometric accuracy. So, the position of the patient must be maintained during imaging and the subsequent delivery of radiation. In general, immobilization systems for SRS can be broadly categorized as invasive, such as the Leksell G frame technique, or non-invasive, such as the double mask technique, and each has various advantages and disadvantages. Both immobilization systems have been used in the RT Department of RSCM located in Jakarta, Indonesia.

Greg A study conducted in the US by Greg et al. 2008 comparing the efficacy of the G frame versus double mask technique found that both techniques had a high degree of accuracy, but the former had better accuracy. This study is the first to compare the accuracies of these techniques in Indonesia [6].

According to Li9, invasive immobilization is the gold standard for SRS with a shift accuracy of ± 0.3 mm, while Gevaert et al. [7] reported a shift accuracy of 0.40 ± 0.30 mm. Comparatively, the shift accuracy of non-invasive immobilization using thermoplastics is 0.58 ± 0.42 mm. A study conducted at RSCM in 2014 by Petrarizyki10 using non-invasive fixation in the form of bite block found the value of shifting in the laterolateral (LL), cranio-caudal (KK), and antero-posterior (AP) axes were 0.61 ± 1.27, 1.13 ± 2.41, and 0.71 ± 1.15 mm, respectively. A study by Lesiuk et al. [8] of 12 patients who received SRT with fixation using a brain lab mask (thermoplastic) reported an average shift of 0.6 mm, suggesting the clinical benefits of a thermoplastic brain mask for patients undergoing SRS.

Stereotactic radiation therapy is one of the excellent services available at SRT is an important service provided by the RT Department of RSCM, but there currently is a lack of data regarding accuracy of the G frame and double mask techniques. Therefore, the aim of the present study was to collect data and identify differences in geometric shifting of patients undergoing stereotactic therapy with a G frame versus a double mask. Additionally, the study also aimed to determine the geometric shifting ratios during stereotactic therapy.

This study was with a G frame versus a double mask.

2. Methods
This cross-sectional comparative study aimed to compare the extent of geometric shifting in stereotactic therapy with the use of a double mask versus a G frame conducted at the RT Department of Cipto Mangunkusumo Hospital. The protocol of this retrospective study of medical record data was approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Indonesia-Cipto Mangunkusumo Hospital. All existing data that met the inclusion criteria of the research were included for analysis until the required number of samples was obtained.

Data of the deviations obtained from verification using an XVI registration algorithm in three axes, namely LL, KK, and AP, were included for analysis. After collection of the verification data, the systematic and random shifting values were calculated to determine an appropriate margin for the planned target volume.

After coding and arrangement of the collected data, cleaning procedure were conducted to ensure consistency of the collected data to avoid shifting. The collected data were then presented in the form of tables and graphs. Univariate and bivariate analyses were performed to compare the degrees of geometry shifting for verification stereotactic therapy with the use of a G frame versus a double mask. Bivariate analysis was conducted with the t-test.

Geometrical shifting in SRS with the Leksell G frame versus that with SRT with a double mask were compared.
3. Results

3.1. Patient characteristics

The average patient age was 46 (range, 7–75) years. Although there were more females (60.90%), there were no significant differences in the sex ratios between the SRT and SRS groups (Table 1).

| Variable          | Frequency | Percentage | Mean | Median | Deviation standard | Min-Max |
|-------------------|-----------|------------|------|--------|--------------------|---------|
| Age               |           |            | 46   | 48     | 16.53              | 7–75    |
| Age               | Male      | 25         | 39.10|        |                    |         |
| Age               | Female    | 39         | 60.90|        |                    |         |
| Sex               | Male      | 25         | 39.10|        |                    |         |
| Sex               | Female    | 39         | 60.90|        |                    |         |
| Technique         | Double mask | 32     | 50.0%|        |                    |         |
| Technique         | G frame   | 32         | 50.0%|        |                    |         |
| Diagnosis         | Schwanoma | 8          | 12.5%|        |                    |         |
| Diagnosis         | Glioma    | 4          | 6.3% |        |                    |         |
| Diagnosis         | Pituitary adenoma | 10    | 15.6%|        |                    |         |
| Diagnosis         | AVM       | 7          | 10.9%|        |                    |         |
| Diagnosis         | Tumor CPA | 6          | 9.4% |        |                    |         |
| Diagnosis         | Metastasis| 6          | 9.4% |        |                    |         |
| Diagnosis         | Meningioma| 6          | 9.4% |        |                    |         |
| Diagnosis         | Others    | 17         | 26.6%|        |                    |         |
| Correction        | Yes       | 47         | 73.4%|        |                    |         |
| Correction        | No        | 17         | 26.6%|        |                    |         |
| Double mask       | Correction| 22         | 68.8 |        |                    |         |
| Double mask       | No Correction | 10   | 31.3%|        |                    |         |
| G frame           | Correction| 25         | 78.1%|        |                    |         |
| G frame           | No Correction | 7    | 21.9%|        |                    |         |

As shown in Table 1, most cases included in this study were pituitary adenomas (15.6%) and Schwanomas (12.5%). At the time of verification of 64 subjects, 17 cases (26.6%) did not require correction (double mask, 10/31.3%; G frame, 7/21.9%).

Based on the type of technique, the average age of the study subjects was the same but when viewed from the data variations, the subjects who received RT with a double mask were more varied.

3.2. Verification results

The verification results using an XVI registration algorithm between patients receiving RT with a double mask versus a G frame both before and after correction of the first fraction were obtained from medical records. The verification results showed deviations in shifting on the LL, KK, and AP axes (Figure 1–3).

The obtained data were then used to calculate the average shifting values, the standard deviation values, and probability (p) value using the Mann–Whitney U test method with SPSS version 20 software (IBM Corp., Armonk, NY, USA).
Figure 1. Shifting of the LL axis with the use of a G frame versus a double mask after correction

Figure 2. Shifting of the KK axis with the use of a G frame versus a double mask after correction

Figure 3. Shifting of the AP axis with the use of a G frame versus a double mask after correction
### Table 2. The average value of the first verification shifting before correction based on the type of fixation devise.

| Variable                  | Mean (mm) | Deviation standard (mm) | p       |
|---------------------------|-----------|-------------------------|---------|
| Laterateral shifting      |           |                         |         |
| Double mask               | 1.5       | 1.4                     | 0.354   |
| G frame                   | 1.1       | 0.8                     |         |
| Kraniokaudal shifting     |           |                         |         |
| Double mask               | 2.6       | 2.6                     | 0.152   |
| G frame                   | 1.4       | 1.2                     |         |
| Anteriopasterior shifting |           |                         |         |
| Double mask               | 1.3       | 1.6                     | 0.732   |
| G frame                   | 1.5       | 2.2                     |         |

As shown in Table 2, there were no significant differences in shifting values (before correction) with the use of a double mask versus a G frame ($p > 0.050$).

### Table 3. The average shifting value after correction based on the type of fixation devise.

| Variable                  | Mean (mm) | Deviation standard (mm) | p       |
|---------------------------|-----------|-------------------------|---------|
| Laterateral shifting      |           |                         |         |
| Double mask               | 0.4       | 0.3                     | 0.074   |
| G frame                   | 0.3       | 0.2                     |         |
| Kraniokaudal shifting     |           |                         |         |
| Double mask               | 0.5       | 0.4                     | 0.083   |
| G frame                   | 0.3       | 0.4                     |         |
| Anteriopasterior shifting |           |                         |         |
| Double mask               | 0.5       | 0.4                     | 0.214   |
| G frame                   | 0.4       | 0.3                     |         |

As shown in Table 3, there were no significant differences in shifting values (after correction) with the use of a double mask versus a G frame ($p > 0.050$).

### 4. Discussion

The use of a 3D coordinate system for SRT ensures a high level of accuracy of the target volume with a minimal dose delivered to the surrounding normal tissue/organs at risk. Sufficient immobilization and verification systems are required to ensure the accuracy and precision of radiation delivery.

Verification can determine the magnitude of shifting at each coordinate point, although the value of each coordinate may differ with subsequent verifications, depending on the position of the patient at the time of CT simulation and irradiation. With good immobilization and positioning, it is expected that the resulting verified value at least fit with the standard value.
In this study, the mean values of XVI shifting verification by cone beam computed tomography were obtained in 32 patients using double mask fixation (noninvasive immobilization). Before correction, the average shift of the LL, KK, and AP axes were 1.5 ± 1.4, 2.6 ± 2.0, and 1.3 ± 1.6 mm, respectively. After correction, the values for the LL, KK, AP axes were 0.4 ± 0.3, 0.5 ± 0.4, and 0.5 ± 0.4 mm, respectively. The average shifting value in this study was almost the same as that reported by Guckenberger et al. [11] with the use of an immobilization thermoplastic double mask versus a single mask (0.9 ± 0.6 mm). Ramakrishna et al. [12] reported a mean shifting value of 0.7 ± 0.5 mm with the use of an immobilized BrainLAB thermoplastic mask (Klarity Medical Products LLC, Newark, OH, USA). Kataria et al. [13] reported mean shifting values with the use of a thermoplastic mask before correction in the LL, KK, and AP axes of 0.4 ± 0.9, 1.1 ± 1.1, and 0.5 ± 1.3 mm, respectively. After correction, these values were 0.11 ± 0.2, 0.2 ± 0.4, and 0.2 ± 0.2 mm, respectively.

The results of the present study before correction were slightly higher than those reported by Kataria et al. [13] of > 1 mm on all three axes. However, the average shifting values after correction were the same as those reported by Kataria et al. [13] of < 0.5 mm, and less than those reported by Guckenberger et al. [11] and Ramakrishna et al. [12].

The mean shifting values of the G frame before on the LL, KK, and AP axes were 1.1 ± 0.8, 1.4 ± 1.2, and 1.5 ± 2.2 mm, respectively. These values after correction were 0.3 ± 0.2, 0.3 ± 0.4, and 0.4 ± 0.3 mm, respectively. Ramakrishna reported a mean total shifting value of 0.4 ± 0.3 mm with the use of the Brown–Robert–Wells invasive head frame immobilization devise.

Kataria et al. [13] reported shifting values on the LL, KK, and AP axes of 1.00 ± 0.3, 0.2 ± 1.2, and 0.1 ± 0.3 mm, respectively, before correction with the use of a G frame and thermoplastic mask. After correction, these values were 0.6 ± 0.22, 0.2 ± 0.15, and 0.0 ± 0.26 mm, respectively. These results were not much different from those of the present study.

In this study, there were no significant differences in the average shifting values before and after correction with the use of a double mask versus a G frame, suggesting that the accuracy with the use of a double mask was equal to that with the use of a G frame. In other words, the accuracy of invasive immobilization was high and not much different from that with noninvasive immobilization with the use of a double mask. The results of this study were in accordance with those reported by Kataria et al. [13], Guckenberger et al. [11] and Ramakrishna et al. [12], where the accuracy of the shifting values was similar with the G frame versus a thermoplastic double mask.

5. Conclusion
There was no significant difference in mean values of geometric shifting with the use of a double versus a G frame for patients undergoing SRT.

References
[1] Stroom J 2000 Safety margins for geometrical uncertainties in radiotherapy Med. Phys. 27 2194.
[2] Lightstone A W, Benedict S H, Bova F J, Solberg T D and Stern R L 2005 Intracranial stereotactic positioning systems: Report of the American Association of Physicists in medicine radiation therapy committee task group no. 68 Med. Phys. 32 2380–2398.
[3] Grosu A-L, Kneschaurek P, Schlegel W, Bortfeld T, eds. New Technologies in Radiation Oncology. Berlin/Heidelberg: Springer-Verlag; 2006.
[4] Nabavi M, Nedaie H A, Salehi N and Naderi M 2014 Stereotactic Radiosurgery / Radiotherapy : A Historical Review Med. Phys. 10 156–67.
[5] Indonesian Ministry of Health. Tumor Otak. 2015:6.
[6] Bednarz G, Machtay M, Werner-Wasik M, et al 2009 Report on a randomized trial comparing two forms of immobilization of the head for fractionated stereotactic radiotherapy Med Phys. 36 12–7.
[7] Gevaert T, Verellen D, Engels B, Haens J D and Ridder M De 2013 Clinical implementation of frameless radiosurgery Belgian. J. Med. Oncol. 7 93–7.
Lesiuk M J, Spencer D P, Chan A K, Voroney J P and Lau H 2012 Image-guided treatment of fractionated stereotactic radiotherapy patients: A quantitative analysis of pre- and post-treatment orthogonal kV images of patients immobilized with thermoplastic masks J. Med. Imaging. Radiat Sci. 43 239–44.

Li Y W T 2014 Determining Rational Planning Target Volume Margins for Intracranial Stereotactic Radiotherapy by Intracranial Stereotactic Radiotherapy

Petrarizky A J 2014 Akurasi Geometri Pasien Yang Menjalani Radioterapi di Departemen Radioterapi RSCM

Guckenberger M, Roesch J, Baier K, Sweeney R A and Flentje M 2012 Dosimetric consequences of translational and rotational shifting in frame-less image-guided radiosurgery Radiat. Oncol. 7 63.

Ramakrishana N, Rosca F, Friesen S, Tezcanli E, Zygmanszki P and Hacker F 2010 A clinical comparison of patient setup and intra-fraction motion using frame-based radiosurgery versus a frameless image-guided radiosurgery system for intracranial lesions. Radiother Oncol. 95 109–115.

Katariya T, Gupta D, Karrthick KP, et al 2013 Frame-based radiosurgery: Is it relevant in the era of IGRT? Neurol India. 61 277–81.