Radiological characteristics of glioblastoma multiforme using CT and MRI examination

Amr A. Abd-Elghany, Abdu Ahmed Naji, Batil Alonazi, Hassan Aldosary, Mohammed Abdulaziz Alsusayan, Mohammed Alnasser, Ebtsam A. Mohammad and Mustafa Z. Mahmoud

ABSTRACT

The purpose of this study was to describe, analyze and characterize computed tomography (CT) and magnetic resonance imaging (MRI) scan of glioblastoma multiforme (GBM) patients. One hundred and three clinically definite GBM patient information, CT and MRI images along with clinical records and demographic data were retrospectively collected from the radiology information system (RIS) database of the Radiology and Medical Imaging Department of King Fahad Medical City between January 2012 to March 2019. Based on our analysis, 70.9% and 29.1% were males and females patients with a mean age of 49.05 ± 14.77 years. The majority of patients (98.1%) were diagnosed with GBM by MRI T2-weighted fluid attenuation inversion recovery (FLAIR) hyperintense scanning protocols, 97.1% diagnosed by MRI T2-weighted hyperintense and 93.2% were diagnosed by an MRI T1-weighted hypointense. About 98.1% of patients had MRI contrast enhancement while 88.1% and 6.8% had a CT hypodense and heterogeneous appearance, respectively. GBM shape in 100% of patients was irregular and the majority (41.8%) of GBM were located in the frontal lobe. In conclusion, this study manages to describe, analyze and characterize the radiological features of GBM in CT and MRI examination.

1. Introduction

Glioblastoma multiforme (GBM) is a tumor that arises from astrocytes cells in the brain and is the most common intracranial tumor of all primary central nervous system that are generally highly malignant (Altwairgi et al., 2016; Khanna et al., 2013). It is usually found in the cerebral hemispheres of the brain, or at times anywhere in the brain or spinal cord. There are two main types of glioblastomas, primary and secondary (Khanna et al., 2013). GBM prognosis scans tremendously poorly with a documented survival rate of roughly 5 years (Altwairgi et al., 2016). Computed tomography (CT) (Figure 1) and Magnetic resonance imaging (MRI) (Figures 2 and 3) play a central role in the diagnosis, characterization, surveillance and therapeutic monitoring of GBM tumors (Gaurav et al., 2017; Walid, 2008).

MRI provides high resolution multi-planar structural information and substantially improved tissue characterization compared to a CT scan. GBM is hypo- or isointense on CT scan, and on the MRI hyperintense on T2-weighted images and hypo- or isointense on T1-weighted images. Nevertheless, edema and mass are variable in appearances. Furthermore, CT and MRI scan (with and without contrast) are very helpful in the management, grading, and staging of tumors (Ginat & Meyers, 2012).

Increasing life expectancy is the major goal for each country. Increased knowledge of disease etiology and continued development of imaging modalities in combination with screening could have positive results in that direction. The database in the developing countries still in progress. It could be of great importance to monitor disease trends for specific pathologies from the radiological point of view in order to decline the mortality rate for a given disease. In the USA solely, around 60% of primary brain tumors were diagnosed as glioblastomas (Walid, 2008).

In Saudi Arabia, there is no clear image and lack number of published articles about the percentage of GBM. It is in view of this that the current study categorizes the radiological features of GBM according to the signs and symptoms from Saudi patients' different ages and compared between two modalities, CT and MRI to know the best modality to detect GBM. Thus, the purpose of this study was to describe, analyze and characterize CT and MRI scan of GBM patients.

CONTACT Mustafa Z. Mahmoud malhassen@psau.edu.sa Radiology and Medical Imaging Department, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, PO Box 422, Al-Kharj 11942, Saudi Arabia

© 2019 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
2. Material and methods

One hundred and three clinically definite GBM data found in the database record of the Radiology and Medical Imaging Department at King Fahd Medical City between January 2012 to March 2019 were retrospectively collected. RIS was used to obtain CT and MRI image records along with patient data and clinical diagnosis. The Institutional Review Board (IRB) (no. 18–118) and Ethical Committee for Research Involving Human Subject approved this study. All patients were Saudi adults and their ages were >18 years old. The exclusion criteria were: i) non-Saudi patients; ii) patients present with other brain lesions beside GBM; and iii) Saudi and non-Saudi patients <18 years old.

All CT studies were performed before and after contrast enhancement with 100 mL iohexol 300 (Omnipaque) on a Siemens 128 slice data acquisition Somaton CT scanner. MRI was performed on a Siemens MRI 1.5 Tesla scanner. T1-weighted, T2-weighted, T2-weighted fluid attenuation inversion recovery (FLAIR) and diffusion-weighted imaging (DWI) were obtained. The slice thickness was 8 mm in both CT and MRI images.

Data collected were analyzed using Statistical Package for Social Science (IBM Corporation, Armonk, NY, USA) version 23 for windows. All measurable data were initially summarized as a mean±standard deviation (SD) in a form of comparison tables. Categorical data, such as the patient’s gender, disease symptoms,
T₁, T₂, T₂ FLAIR and DWI MRI appearance, MRI contrast enhancement, CT appearance, CT contrast enhancement, necrosis, lobe size, and hemispheric site were presented as frequencies and relative percentages. Continuous variable such as patients’ age and GBM size was expressed as mean±SD. The Chi-square test (x² test) was applied to determine the relationship between categorical variables mentioned above. The Mann–Whitney U test, which is a nonparametric test of the null hypothesis, was used to whether there were differences between male and female patients in terms of their GBM size. Spearman’s rank correlation coefficient (Spearman’s Rho correlation coefficient) which is a nonparametric version of the Pearson correlation coefficient was used to decipher the relationship between patient’s age and GBM size. A p-value <0.05 was considered as statistically significant.

3. Results

In this study, 103 definite GBM patients’ data (73 males, 70.9%, and 30 females, 29.1%) were retrospectively collected and analyzed based on the available clinical record from King Fahd Medical City, Riyadh, Saudi Arabia. Patient’s age range was between 18 and 78 years with a mean age of 49.05 ± 14.77 years. The GBM mean size was 19.17 ± 14.29 cm³ with relative symptoms of headache (30.1%), seizure (14.6%), headache and seizure (1.19%) and other complication (53.4%), respectively (Table 1).

In MRI T₁-weighted sequence, 93.2% of GBM were found to be hypointense and 4.9% were found to have a classical isointense appearance, while in MRI T₂-weighted they having hyperintense (97.1%) and heterogeneous (1.9%) appearance. However, in sequences of MRI T₂-weighted FLAIR, majority of GBM (98.1%) were of the hyperintense appearance and only (1.9%) presented with a heterogeneous appearance. In MRI DWI, 98.1% of GBM were presented with a restricted water diffusion and 1.9% of them were with no water-restricted diffusion. All GBM patients in MRI perfusion test were characterized with an increase of their relative cerebral blood volume (rCBV). In terms of contrast enhancement, 98.1% of GBM patients had an MRI contrast enhanced while only 1.9% of them were not presented with contrast enhanced (Table 1).

For CT appearance, 88.4% of GBM were of the hypodense appearance while only 6.8% of these mass was heterogeneous in appearance. In addition, 95.1% of the patients diagnosed with GBM were not on the need for CT contrast enhancement, while only 4.9% of GBM were enhanced. Besides the majority of the patients (89.3%) presents with necrotic GBM, GBM shape was irregular in all diagnosed cases. CT examination presented that the location of GBM was 41.8% located in the frontal lobe, 31.1% located in the temporal lobe, while the rest (27.2%) was located in occipital lobe, parietal lobe, and posterior fossa and thalamic region. GBM lesions were also detected in the right and left-brain hemispheres by a percentage of 48.5% and 51.5%, respectively (Table 1).

The authors test the relationship between enhanced and non-enhanced MRI examination in the diagnosed GBM patients. Where $|x| = 9, p = 0.03$, implying a significant relationship (Table 2).

A non-significant relationship was noted between male and female patients in term of GBM appearance in CT and T₁-weighted MRI examination, where $|x| = 3.231, p = 0.357$, $|x| = 0.99, p = 0.999$ respectively. In addition, another non-significant relationship

### Table 1. Basic demographics and clinical characteristics of GBM patients.

| Characteristics | Descriptions | n (%) |
|-----------------|--------------|-------|
| Gender          | Male         | 73 (70.9%) |
|                 | Female       | 30 (29.1%) |
| Age (years)     | Mean±SD      | 49.05 ± 14.77 |
|                 | Median       | 52 |
|                 | Age range    | 18–78 |
| GBM size (cm³)  | Mean         | 19.17 ± 14.29 |
| Signs and symptoms | Headache | 31 (30.1%) |
|                 | Seizure      | 15 (14.6%) |
| MRI T₁-weighted | Hypeointense | 96 (92.2%) |
|                 | Isointense  | 5 (4.9%) |
|                 | Hyperintense| 1 (1%) |
|                 | Heterogeneous| 1 (1%) |
| MRI T₂-weighted | Hyperintense | 100 (97.1%) |
|                 | Isointense  | 1 (1.0%) |
|                 | Heterogeneous| 2 (1.9%) |
| MRI T₂-weighted FLAIR | Hyperintense | 101 (98.1%) |
|                 | Heterogeneous| 2 (1.9%) |
| MRI DWI         | Restricted water diffusion| 101 (98.1%) |
|                 | No water restricted diffusion| 2 (1.9%) |
| MRI perfusion   | Enhanced     | 101 (100%) |
|                 | Non-enhanced | 2 (1.9%) |
| CT appearance   | Hypodense    | 91 (88.4%) |
|                 | Isodense     | 3 (2.9%) |
|                 | Heterogeneous| 7 (6.8%) |
|                 | None         | 2 (1.9%) |
| CT contrast enhancement | Enhanced | 5 (4.9%) |
|                 | No contrast given to the patient| 98 (95.1%) |
| Necrosis        | Yes          | 92 (89.3%) |
|                 | No           | 9 (8.7%) |
| Resection       | 2 (1.9%) |
| Shape           | Irregular    | 103 (100%) |
| GBM location    | Frontal lobe | 43 (41.8%) |
|                 | Occipital lobe| 4 (3.9%) |
|                 | Parietal lobe| 19 (18.5%) |
|                 | Posterior fossa| 3 (2.9%) |
|                 | Temporal lobe| 32 (31.1%) |
|                 | Thalamus     | 2 (1.9%) |
| Hemispheric location | Right brain hemisphere| 50 (48.5%) |
|                 | Left brain hemisphere| 53 (51.5%) |

### Table 2. The relationship between enhanced and non-enhanced MRI examination in the diagnosed GBM patients.

| MRI contrast enhancement | Enhanced (n = 4) | Non-enhanced (n = 99) | $x^2$ (df) | p-value* |
|--------------------------|------------------|-----------------------|------------|----------|
| Enhanced                 | 4 (3.88%)        | 99 (96.12%)           | 9.00       | 0.03     |
| Non-enhanced             | 1 (0.97%)        | 1 (1.0%)              |            |          |

*Chi-square test
Male

The relationship between gender, MRI contrast enhancement, brain lobes and hemispheric location with necrotic changes of GBM in the diagnosed patients.

**4. Discussion**

GBM occurs mostly in the subcortical region of the white matter of the brain (Jayachandran, Jonathan, Patel, & Prabhu, 2018). CT and MRI scans with or without contrast are helpful in grading and management of this deadly disease (Helseth & Mork, 1989). CT and MRI were generally the methods of choice for proper diagnosis of this brain tumor and CT was chosen only when MRI was found to be contradictory. The GBM patients' records were retrospectively obtained and analyze to explore any clinical or scientific insight from the data. The incidence of GBM discovered in this study was predominantly higher in males 70.9% than in females, supporting the previous findings by Ostrom et al. (2015). The mean age of 49.05 years was found among patients studied with a mean average of GBM tumor size of 19.17 cm³, which was in contrast to the findings reported by Jeswani et al. (2013). The frequent GBM sites in this study were the frontal lobe, followed by temporal and parietal lobes. This was similar to many reports that found frontal lobe as the most common site for GBM (Ferreira, Barbosa, Amaral, Mendonça, & Lima, 2004; Lacroix et al., 2001). Although a study conducted in Zurich demonstrated that the most common sites of this tumor were temporal, parietal, frontal and occipital lobes, respectively (Barnard & Geddes, 1987).

Patients’ symptoms were mostly headache and seizure. This was in line with the previous findings of Sizoo et al. (2010). Most of the patients were diagnosed by an MRI T₁-weighted hypointense, MRI T₂-weighted hyperintense, and MRI T₂-weighted FLAIR hyperintense. Timmons et al. (2018) reported similar findings in a review. In addition, the authors discovered that 98.1% of GBM patients characterized by MRI contrast enhancement while 88.1% had a CT hypodense appearance with only 6.8% had a heterogeneous CT appearance. Barker, Davis, Chang, and Prados (1996) and Liu et al. (2017) reported the same findings. About 48.6% of GBM lesions located in a single brain hemisphere while the rest located

---

**Table 3. CT and MRI appearance among GBM patients.**

| MRI appearance | CT appearance | N/A | Heterogeneous | None | $x^2(df)$ | p-value* |
|----------------|-------------|-----|---------------|------|------------|---------|
| Hypointense | Isodense | 3 (2.91%) | 84 (81.6%) | 7 (6.8%) | 2 (1.94%) | 0.990 | 0.999 |
| Isodense | Hypodense | 0 (0.00%) | 5 (4.85%) | 0 (0.00%) | 0 (0.00%) | 0.407 | 0.999 |
| Hyperintense | Heterogeneous | 0 (0.00%) | 1 (0.97%) | 0 (0.00%) | 0 (0.00%) | 0.269 | 0.966 |
| Isodense | FLAIR Hyperintense | 0 (0.0%) | 2 (1.94%) | 0 (0.00%) | 0 (0.00%) | 0.269 | 0.966 |
| Heterogeneous | FLAIR Hypodense | 0 (0.0%) | 2 (1.94%) | 0 (0.00%) | 0 (0.00%) | 0.269 | 0.966 |

---

**Table 4. The relationship between gender, MRI contrast enhancement, brain lobes and hemispheric location with necrotic changes of GBM in the diagnosed patients.**

| Variables | Necrosis | Gender | Male | Female | Rejection | $x^2(df)$ | p-value* |
|-----------|----------|--------|------|--------|-----------|----------|---------|
| MRI contrast enhancement | Yes | No | Resection | FLAIR Hyperintense | 0.575 |
| Enhanced | 64 (62.1%) | 7 (6.8%) | 2 (1.9%) | 1.106 |
| Non-enhanced | 28 (27.2%) | 2 (1.9%) | 0 (0.0%) | 4.367 | 0.113 |
| Occipital lobe | 4 (3.9%) | 0 (0.0%) | 0 (0.0%) | 4.608 | 0.912 |
| Parietal lobe | 19 (18.4%) | 0 (0.0%) | 0 (0.0%) | 0.022 |
| Temporal lobe | 27 (26.1%) | 4 (36.4%) | 1 (0.9%) | 0.022 |
| Posterior fossa | 3 (2.9%) | 0 (0.0%) | 0 (0.0%) | 0.022 |
| Thalamus | 2 (1.9%) | 0 (0.0%) | 0 (0.0%) | 0.022 |
| Right hemisphere | 47 (45.6%) | 6 (5.8%) | 0 (0.0%) | 14.786 | 0.022 |
| Left hemisphere | 41 (39.8%) | 2 (1.9%) | 2 (1.9%) | 0.022 |
| Middle | 0 (0.0%) | 1 (0.9%) | 0 (0.0%) | 0.022 |
| Bilateral | 4 (3.9%) | 0 (0.0%) | 0 (0.0%) | 0.022 |

---

*Chi-square test
Table 5. Difference between male and female patients in terms of GBM size.

| Variable     | Patient’s gender | n (%) | Mean±SD | p-value* |
|--------------|------------------|-------|---------|----------|
| GBM size     | Male             | 73 (70.9%) | 19.17 ± 14.29 | 0.087 |
|              | Female           | 30 (29.1%)  |         |          |

*Mann–Whitney U test

Bilaterally. A significant relationship (p < 0.03) was presented between cases of GBM with contrast enhancement and cases without contrast enhancement, whereas no significant association observed among all MRI appearances (p > 0.05) of GBM. Mann–Whitney U test revealed no difference between males and females patients in terms of GBM size (p > 0.05).

To our knowledge, this was the first study conducted to describe, analyze and characterize CT and MRI scan of GBM in Saudi adults. This study was limited to only one hospital in Saudi Arabia and the samples were not covering the completely Saudi population; hence, further study needs to be embarked in order to fully draw a conclusive study in Saudi Arabia as a country. Other limitations include a relatively small sample size that diagnosed in a single center origin, which unfortunately might affect the accuracy of current findings and in fact, significantly reduces the power of current conclusions.

5. Conclusion

In conclusion, this study manages to describe, analyze and characterize the radiological features of GBM in CT and MRI examination. GBM is more prevalent in adult Saudi males rather than females and there was no significant difference between them in terms of GBM size. An association between brain hemispheres and necrosis of GBM was observed and a link between MRI contrast and non-contrast enhancement was revealed. In agreement with several studies, the most common location of glomas in our study was the frontal lobe. However, further studies need to be carried out to explore other descriptive findings that were limited in this study.

Acknowledgments

The authors would like to thank the staff of the Department of Radiology and Medical Imaging in King Fahad Medical City and King Khalid University Hospital for their cooperation and support.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Batil Alonazi http://orcid.org/0000-0003-2942-9516
Mustafa Z. Mahmoud http://orcid.org/0000-0003-2552-9165

References

Altwairgi, A. K., Alqareeb, W., Yahya, G., Maklad, A. M., Aly, M. M., Al Shakweer, W., ... ELYAMANY, A. (2016). Outcome of patients with glioblastoma in Saudi Arabia: Single center experience. *Molecular and Clinical Oncology, 4, 756–762.*

Barker, F. G., 2nd, Davis, R. L., Chang, S. M., & Prados, M. D. (1996). Necrosis as a prognostic factor in glioblastoma multiforme. *Cancer, 77, 1161–1166.*

Barnard, R. O., & Geddes, J. F. (1987). The incidence of multifocal cerebral gliomas. A histologic study of large hemisphere sections. *Cancer, 60, 1519–1531.*

Ferreira, N. F., Barbosa, M., Amaral, L. L., Mendonçãa, R. A., & Lima, S. S. (2004). Magnetic resonance imaging in 67 cases of glioblastoma multiforme and occurrence of metastases. *Arquivos De Neuro-Psiquiatria, 62, 695–700.*

Gaurav, S., Gregory, S. A., Spyridon, B., Rahul, N., Kiran, T., Joshua, D., et al. (2017). Advanced magnetic resonance imaging in glioblastoma: a review. *Chinese Clinical Oncology, 6, 40.*

Ginat, D. T., & Meyers, S. P. (2012). Intracranial lesions with high signal intensity on T1-weighted MR images: differential diagnosis. *Radiographics, 23, 499–516.*

Helseth, A., & Mork, S. J. (1989). Neoplasms of the central nervous system in Norway. III. Epidemiological characteristics of intracranial gliomas according to histology. *Acta Pathologica, Microbiologica Et Immunologica Scandinavica, 97, 547–555.*

Jayachandran, A., Jonathan, G. E., Patel, B., & Prabhuk, K. (2018). Primary spinal cord glioblastoma metastasizing to the cerebellum: A missed entity. *Neurology India, 66, 854–857.*

Jeswani, S., Nuño, M., Fulkerts, V., Mukherjee, D., Black, K. L., & Patil, C. G. (2013). Comparison of survival between cerebellar and supratentorial glioblastoma patients: Surveillance, epidemiology, and end results (SEER) analysis. *Neurosurgery, 73, 240–246.*

Khanna, A., Venteicher, A. S., Walcott, B. P., Kahle, K. T., Mordes, D. A., William, C. M., ... Ogilvy, C. S. (2013). Glioblastoma mimicking an arteriovenous malformation. *Frontiers in Neurology, 4, 144.*

Lacroix, M., Abi-Said, D., Fourney, D. R., Gokaslan, Z. L., Shi, W., DeMonte, F., ... Sawaya, R. (2001). A multivariate analysis of 416 patients with glioblastoma multiforme: Prognosis, extent of resection, and survival. *Journal of Neurosurgery, 95, 190–198.*

Liu, S., Wang, Y., Xu, K., Wang, Z., Fan, X., Zhang, C., ... Jiang, T. (2017). Relationship between necrotic patterns in glioblastoma and patient survival: Fractal dimension and lacunarity analyses using magnetic resonance imaging. *Scientific Reports, 7, 8302.*

Ostrom, Q. T., Gittleman, H., Fulop, J., Liu, M., Blanda, R., Kroemer, C., ... Barnholtz-Sloan, J. S. (2015). CBTRUS statistical report: Primary brain and central nervous system tumors diagnosed in the united states in 2008–2012. *Neuro- oncology, 17, iv1–iv62.*

Sizoo, E. M., Braam, L., Postma, T. J., Pasman, H. R., Heimans, J. J., Klein, M., ... Taphoorn, M. J. B. (2010). Symptoms and problems in the end-of-life phase of high-grade glioma patients. *Journal of Neuro- Oncology, 12, 1162–1166.*

Timmons, J. J., Zhang, K., Fong, J., Lok, E., Swanson, K. D., Gautam, S., & Wong, E. T. (2018). Literature review of spinal cord glioblastoma. *American Journal of Clinical Oncology, 41, 1281–1287.*

Walid, M. S. (2008). Prognostic factors for long-term survival after glioblastoma. *The Permanente Journal, 12, 45–48.*