

Determining the applicability of the RSNA radiology lexicon (RadLex) in high-grade glioma MRI reporting – a preliminary study on 20 consecutive cases with newly diagnosed glioblastoma

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Abstract

Purpose

The implementation of a collective terminology in radiological reporting such as the RSNA radiological lexicon (RadLex) yields many benefits including unambiguous communication of findings, improved education, and fostering data mining for research purposes. While some fields in general radiology have already been evaluated so far, this is the first exploratory approach to assess the applicability of the RadLex terminology for glioblastoma multiforme (GBM) MRI reporting.

Methods

Preoperative brain MRI reports of 20 consecutive patients with newly diagnosed GBM (mean age 68.4 ± 10.8 years; 12 males) between January and October 2010 were retrospectively identified. All terms related to the tumor as well as their frequencies of mention were extracted from the MRI reports by two independent neuroradiologists. Every item was subsequently analyzed with respect to an equivalent RadLex representation and classified into one of four groups as follows: 1. verbatim RadLex entity, 2. synonymous/multiple equivalent(s), 3. combination of RadLex concepts, or 4. no RadLex equivalent. Additionally, verbatim entities were categorized using the hierarchical RadLex Tree Browser.

Results

A total of 160 radiological terms were gathered. 123/160 (76.9%) items showed literal RadLex equivalents, 9/160 (5.6%) items had synonymous (non-verbatim) or multiple counterparts, 21/160 (13.1%) items were represented by means of a combination of concepts, and 7/160 (4.4%) entities could not eventually be transferred adequately into the RadLex ontology.

Conclusions

Our results suggest a sufficient term coverage of the RadLex terminology for GBM MRI reporting. If applied extensively, it may improve communication of radiological findings and facilitate data mining for large-scale research purposes.

Introduction

There are numerous substantial benefits resulting from implementing a common language in radiology reporting. A common terminology allows for unambiguous interdisciplinary communication of findings, education of radiology residents, quality improvement, and research facilitation including data mining with the help of large-scale databases (**Dunnick 2008, Kahn 2009**) [1,2]. Therefore, the Radiological Society of North America (RSNA) supported by the American College of Radiology, the College of

American Pathologists, the National Institute of Biomedical Imaging and Bioengineering (NIBIB), the cancer Biomedical Informatics Grid (caBIG) as well as numerous other professional organizations established a comprehensive radiological lexicon termed RadLex that aims to cover the whole field of medical imaging comprising of all different radiological subspecialties (**Website RadLex 2020, Langlotz 2006**) [3,4]. Even though the title RadLex implies that it might only be a conventional lexicon defining specific radiological items, in fact it should rather be regarded as an ontology which does not only contain standardized concepts and definitions. Additionally, it provides extensive background information on their specific relationships (**Website RadLex 2020, Rubin 2008**) [3,5]. A few years after the release of the first version of this radiological terminology in English language in 2005, a translation into German language was published that already comprised of more than 6,000 items (**Marwede 2009**) [6]. Since then, both the English and German editions of the RadLex have continuously been updated and augmented and the current version 4.0 of this radiology domain lexicon already contained more than 46,000 entities at the time of publication in January, 2019 (**RadLex Release Notes 2019**) [7]. RadLex has demonstrated the most excellent results compared to other developed vocabularies in indexing radiological content collected from peer-reviewed biomedical publications, where nearly all images could be annotated with one or even multiple RadLex terms (**Kahn 2014**) [8]. Unfortunately, due to its manual top-down construction by experts in the field, the RadLex ontology remains, by its very nature, incomplete with a large body of empirical literature revealing gaps of coverage in certain radiological fields such as mammography and chest computed tomography (**Marwede 2008, Bulu 2018, Deshpande 2020**) [9–11]. Focusing on the neurooncological domain of the neuroradiology subspecialty, to date there is no information on the applicability, performance and coverage of the RadLex vocabulary with respect to glioblastoma multiforme (GBM) magnetic resonance imaging (MRI) findings, which are known to be the most common malignant primary brain tumors (World Health Organization classification of tumors of the central nervous system grade IV) of astrocytic origin with an increased incidence with age (**Ostrom 2015**) [12]. On these grounds, we aimed to determine the transferability of free-text German-speaking MRI reports on newly diagnosed GBM cases into RadLex terminology.

Methods

Ethics

Prior to data collection, the study protocol was formally approved by the Institutional Review Board of the University Medical Center Göttingen (registration number: 8/8/20). All steps of the course of this investigation are in line with the Declaration of Helsinki adopted by the World Medical Association General Assembly in 1964 and its later amendments (**World Medical Association 2013**) [13].

Patients and procedures

After formal study protocol approval, 20 consecutive preoperative MRI reports of patients with newly diagnosed primary GBM between January 2010 and October 2010 were retrospectively identified by means of a comprehensive neurooncological database provided by the local department of neurosurgery.

The definite confirmation of GBM diagnosis (19X primary GBM, 1X primary gliosarcoma) was established by our colleagues of the department of neuropathology in all cases. A gliosarcoma is a rare biphasic glial and sarcomatous variant of GBM with similar prognosis following standard treatment (**Frandsen 2019**) [14]. Pathological diagnoses of all included grade 4 astrocytic tumors (GBM, gliosarcoma) were based on the well-established criteria set out in the contemporary fourth edition of the World Health Organization classification of tumors of the central nervous system (**Louis 2007**) [15]. All preoperative brain MRI imaging was performed at our tertiary care neuroradiology center using a 3.0 Tesla MRI scanner (TrioTim; Siemens, Erlangen, Germany). Images were acquired in accordance with the latest European Society of Neuroradiology (ESNR) recommendations for glioma imaging developed from the protocol jointly published by the European Organization for Research and Treatment of Cancer (EORTC) and the United States National Brain Tumor Society (NBTS), which include at least isotropic 3D T1 weighted images before and after contrast agent application, axial 2D 3-directional diffusion weighted imaging, axial 2D T2-weighted turbo spin-echo sequences, axial 2D T2-weighted fluid attenuated inversion recovery sequences, and dynamic susceptibility contrast MR perfusion (**Ellingson 2015, Thust 2018**) [16,17]. Presurgical MRI scans of all patients were independently assessed by two neuroradiologists. Following the imaging procedure, all patients underwent near-term cranial neurosurgery within the next days to weeks (mean 4.4 ± 5.1 days).

Data collection and processing

MRI reports were retrieved from the hospital's radiology information system (NEXUS / DIS GmbH, Frankfurt am Main, Germany). Additionally, neuropathological results were collected from the electronic medical records (IXSERV, ix.mid Software Technologie GmbH, Köln, Germany). The following data were gathered: demographic patient information including age and gender, type of surgery, neuropathological confirmation of GBM diagnosis from intraoperatively obtained tissue specimen, reporting neuroradiologists, all terms and concepts describing the tumors and their effects on surrounding brain tissues included in the findings section of the MRI reports. A list of all utilized terms was compiled and a translation into English language performed. Subsequently, the RadLex Term Browser was queried twice for each item (English and German) to find verbatim equivalents represented by a unique RadLex identification number (RID) (group 1) (**RadLex Term Browser 2020**) [18]. For terms, which could not be matched with a single equivalent literal RadLex item, common clinical synonyms were also added to the database search (group 2). These elements were separated from those items with a single univocal RadLex match due to the difficulties with a view to reporting exact frequencies. In case of a negative result, we tried to combine existing RadLex entities to cover the meaning of the items unrepresented so far (group 3). The remainder of terms delineates concepts that could neither be translated directly nor via an appropriate combination of existing RadLex entities (group 4). Accordingly, each and every extracted term was categorized into one of these four prespecified groups. Moreover, the frequency of term utilization in GBM reporting (n = 20) was determined. Concepts revealing a word-for-word representation in RadLex were further investigated with respect to their first order and also subordinate RadLex categories. For this purpose, the hierarchical RadLex Tree Browser was employed. All analyses were independently performed by two neuroradiologists (one of both is also a board certified neurosurgeon)

and incongruities regarding assignments of items were solved by consensus. Flowchart_study protocol outlines the principal course of the study.

Results

Patients and clinical data

The study cohort comprised of a total of 20 adult GBM patients with a mean age of 68.4 ± 10.8 years. There was a preponderance of male cases (60.0%; 12/20). The vast majority of patients underwent gross total GBM resection (80.0%; 16/20) and a minority of 15.0% (3/20) presented with symptomatic epilepsy. Detailed information on demographics, diagnoses, and surgical treatment is provided by table 1_demographic and clinical data.

Analysis of terms utilized in high-grade glioma MRI reporting

In-depth screening of the findings sections of the preoperative brain MRI reports on all 20 GBM patients was independently performed by two neuroradiologists and revealed a total number of 160 discrete items. The MRI reports were authored by ten experienced radiologists in total, who were not involved in the conduct of this study. 76.9% (123/160) of the extracted terms were attributable to a univocal verbatim RadLex entity. 51.2% (63/123) of these concepts with corresponding word-for-word RadLex equivalents were seen repetitively in $\geq 10\%$ of the MRI reports. The most frequently utilized RadLex terms identified in at least half of the reports ($\geq 50\%$) were “central” (RID 5827; 14/20 cases), “mass” (RID 3874; 12/20 cases), “necrosis” (RID 5171; 12/20 cases), “restricted diffusion” (RID 43349; 10/20 cases) and “rim enhancement” (RID 34303; 13/20 cases). A complete list of all these 123 items with verbatim RadLex matches including their German counterparts, corresponding RIDs, categorization, and prevalences in GBM MRI reporting is available as a supplement_terms with univocal RadLex ID to this publication. Hierarchical classification of directly attributable RIDs into first order RadLex categories showed that most of these items fell into one of the two main categories *ana* \rightarrow *micalentity* (39.0%; 48/123) or *RadLexdescrip* \rightarrow *r* (31.0%; 38/123), whereas the other four remaining categories together comprised of the residual 30.0% (37/123) of concepts, as presented in figure_categorization of univocal RadLex terms. Another group was set up for terms with synonymous/conceptually equivalent (i.e. non-verbatim) RadLex items and concepts with equivocal/multiple corresponding ontological RadLex entities. This group encompassed 5.6% (9/160) of all extracted elements. The most commonly encountered concepts of this cluster were *max* (3/20 cases) and *space occupying* (4/20 cases). Table 2_terms with non-verbatim/synonymous or multiple equivalent RadLex matches shows all terms belonging to the second group with their respective RadLex synonyms as well as frequencies of mention in MRI reports on GBM. 13.1% (21/160) of items could only be covered by a combination of appropriate RadLex entities. Perifocal edema (14/20 cases) and facilitated diffusion (5/20 cases) were the most frequently employed elements in this third category. A proposal regarding RadLex transfer options and frequency of use of all these third category terms is presented in table 3_terms covered by a combination of RadLex entities.

4.4% (7/160) of items could eventually not be transposed into existing RadLex nomenclature. Besides specific pictorial descriptions (e.g. garland-like enhancement, finger-shaped edema, areal/planar tumor spread, tumor tail), there were also other terms of infrequent usage such as blood-brain barrier disruption and main lesion (both concepts found in < 10% of MRI reports). In addition, RadLex offers no possibility to record an exact size measurement of a mass in centimeters. The extent of a tumor could either be described by coarse segmentation into small (RID 5774), medium (RID 5775), and large (RID 5778) or alternatively less than 10 millimeters (RID 49805), 10–19 millimeters (RID 49806), and 20 millimeters or greater (RID 49824). Both variants lack accuracy with respect to precise characterization of the dimensions of a specific lesion.

Discussion

20 consecutive free-text brain MRI reports on patients with newly diagnosed GBM were transposed into the current version of the RadLex ontology. More than 95% of descriptive terms used in these reports were satisfactorily covered by means of verbatim, synonymous, or combinations of existing RadLex items. More than a decade ago, Marwede and colleagues investigated a preliminary RadLex version with regard to indexing of thoracic computed tomography reports and observed a degree of completeness of 84% for this radiological subspecialty (**Marwede 2008**) [9]. Furthermore, an analysis of a large set of published radiology reporting templates demonstrated a partial or complete match between 2,509 extracted unique terms and corresponding RadLex elements in a proportion of 67% (**Hong 2012**) [19]. A comprehensive evaluation of more than 385,000 radiology-centric figure captions gathered from 613 peer-reviewed medical journals revealed the best term mapping performance for RadLex compared to five other biomedical ontologies despite comprising fewer items (**Kahn 2014**) [8]. Since then, the Radiological Society of North America has made huge efforts to elaborate and extend this controlled vocabulary. Therefore, the current fourth version of RadLex includes more than 46,600 distinct entities (**RadLex Release Notes 2019**) [7]. Nonetheless, there remains an inherent risk of fragmentariness of the RadLex ontology owing to its top-down construction process by expert committees with experience in various radiological subdomains (**Langlotz 2006**) [4]. Fortunately, several attempts have been undertaken in the past to overcome this structural downside by means of automatic software based extraction of terms from different large-scale sources including a corpus of Pubmed repository articles as well as an enormous set of 270,540 free-text mammography reports (**Bulu 2018, Hazen 2011**) [10,20]. The latter study was performed with the aid of natural language processing, which could be an option to expand other radiology domains as well by using this complementary approach. Shore and colleagues scrutinized books, radiological articles, dictionaries, and biomedical webpages for names and synonyms of imaging signs that were subsequently integrated into RadLex's "imaging observation" section to improve its applicability (**Shore 2012**) [21]. Following this bottom-up concept, we manually analyzed consecutive free-text brain MRI reports of a cohort of high-grade glioma patients. The assessment displayed a small fraction of terms (< 5.0%) that could not be attributed to a specific RadLex entity or RID combination, respectively. First of all, the lexicon lacks options to communicate the exact magnitude of a specific tumorous lesion. Apart from coarse size descriptors such as small, medium, and large or

alternatively less than 10 millimeters, 10–19 millimeters, and 20 millimeters or greater, there is no further possibility of refining this important characteristic (**Website RadLex 2020**) [3]. Especially in view of patients suffering from GBM, spatial tumor dimensions are a well-established independent prognostic factor with respect to overall survival together with other clinicopathological features such as greater extent of resection, younger patient age, better physical condition, and eventually O-6-methylguanine-DNA-methyltransferase promoter methylation status (**Raysi Dehcordi 2012, Capellades 2018**) [22,23]. Bearing in mind this clinical implication, we would welcome the implementation of more detailed size descriptors in the upcoming updates on the RadLex vocabulary. Furthermore, the concept of blood-brain barrier disruption was stated in one of the surveyed radiological documents and could not be matched adequately by any RID. On the one hand, it is not possible to visualize the blood-brain interface directly via conventional MRI - what you might see is a T1 enhancement due to extravasation of contrast medium into the extracellular space as a result of a disruption of this neuroprotective barrier, but not the barrier itself (**Heye 2014, Varatharaj 2019**) [24,25]- and therefore it could be argued that this concept may be expendable. On the other hand, a primary range of the RadLex application involves indexing of large databases of radiological free-text reports for educational and research purposes, which necessarily requires the highest achievable degree of completeness (**Website RadLex 2020, Marwede 2009**) [3,6]. Hence the issue of implementation of a specific term into RadLex should be decided upon preferably by the fact how deeply ingrained this concept is in our radiological everyday communication. A substantial part of items that were represented in the analyzed GBM MRI reports and not attributable to any specific RadLex entities could be delineated as pictorial signs, such as finger-shaped brain edema or garland-like tumor enhancement. Despite a certain lack of objectivity of such descriptions, these kinds of figurative terminological elements have been appreciated and widely accepted by radiologists for interpretations in neuroimaging right from the beginning of the era of clinical computed tomography application (**Kazner 1975, Fiegler 1986**) [26,27]. As early as in the mid-seventies of the twentieth century a pioneer report on the diagnostic possibilities of cranial computed tomography made references to tumor-related white matter brain edema “producing finger-like shapes” in a large cohort of patients (**Kazner 1975**) [26]. If the RadLex terminology is meant to be a common lingua franca for the radiological community, it should be oriented towards the principles of general language evolution. The Duden dictionary, first published by Konrad Duden in 1880, provides the preeminent language resource of the German language and states the authoritative rules regarding utilization of German language. It is regularly updated and the editorial decision on inclusion of a particular word or phrase is mainly based on its frequency and longevity of use (**Duden 2020**) [28]. Because of the widespread adoption and long-term usage of the above mentioned figurative radiological terms we propose the augmentation of the RadLex vocabulary with these elements. This approach would be well in line with the general policy pursued by the Duden curators in terms of everyday language. The synergy of a continuously expanded and updated RadLex terminology adapted to everyday practice and a set of essential morphologically describable features, as developed in the VASARI project for brain tumors by The Cancer Imaging Archive (TCIA), has the potential to sustainably improve the quality, precision, and communication of MRI reporting of GBM (**VASARI Research Project 2021**) [29].

This study is not without limitations. The monocentric study design as well as a relatively small sample size make up downsides of the survey potentially compromising its generalizability. On the other hand, the clearly defined eligibility criteria and thorough scrutiny of all consecutive MRI reports by two independent neuroradiological raters assure an explicit statement on the issue of the applicability of RadLex in GBM MRI reporting. Moreover, the included MRI reports were authored by a large group of ten experienced neuroradiologists all contributing their specific reporting style and vocabulary, which may increase the variability of the terms used and thus tests the basic practicability of the RadLex ontology studied in this specific neuro-oncological context.

Conclusion

In conclusion, radiological image interpretation should ultimately focus on the obtainment of precise, unambiguous, consistent, and complete reports as this profoundly improves the communication of findings to referring physicians or other medical specialists and may consequently contribute to better patient care and outcome (**Dunnick 2008, Siström 2005, Kahn 2009, Mamlouk 2018**) [1,2,30,31]. To reach that aim, the two most important and indispensable cornerstones are the utilization of a system of unequivocally understood and well-established linguistic concepts as well as the application of structured templates. The thorough investigation of a consecutive set of GBM MRI reports unveiled a high rate of item coverage for the RadLex terminology underscoring its representativity in this specific setting. Therefore, RadLex offers a sufficient English- and German-language tool for high-grade glioma reporting that undergoes continuous further adjustment to the needs of its users, the radiological community. Apart from refinement in professional communication, propagated employment of this lexicon has also the potential to advance neuroradiological education, health care quality management, and research efforts based on data mining via natural language processing.

Abbreviations

GBM – glioblastoma multiforme

MRI – magnetic resonance imaging

RadLex – radiology lexicon developed by the Radiological Society of North America

RID – RadLex identification number

Declarations

Ethics approval

All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later

amendments or comparable ethical standards. The study protocol was formally approved by the Institutional Review Board of the University Medical Center Göttingen (registration number: 8/8/20).

Consent to participate

In consultation with the Institutional Review Board of the University Medical Center Göttingen, patient informed consent was waived due to the entirely retrospective nature of the analysis. The study protocol does not contain any procedures involving human subjects.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests

The authors declare that they have no conflict of interest.

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No funding was received for this study.

Authors' contributions

Torge Huckhagel and Christian Riedel conceived the study. Torge Huckhagel collected data. Torge Huckhagel and Christian Riedel analyzed data. Torge Huckhagel, Christian Riedel, Christine Stadelmann, and Tammam Abboud contributed to the manuscript and approved the final text prior to submission.

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References

1. Dunnick NR, Langlotz CP. The Radiology Report of the Future: A Summary of the 2007 Intersociety Conference. *Journal of the American College of Radiology*. 2008;5:626–9.
2. Kahn CE, Langlotz CP, Burnside ES, Carrino JA, Channin DS, Hovsepian DM, et al. Toward Best Practices in Radiology Reporting. *Radiology*. 2009;252:852–6.
3. RadLex radiology lexicon [Internet]. [cited 2020 Oct 17]. Available from: <https://www.rsna.org/en/practice-tools/data-tools-and-standards/radlex-radiology-lexicon>

4. Langlotz CP. RadLex: A New Method for Indexing Online Educational Materials. *RadioGraphics*. 2006;26:1595–7.
5. Rubin DL. Creating and Curating a Terminology for Radiology: Ontology Modeling and Analysis. *J Digit Imaging*. 2008;21:355–62.
6. Marwede D, Daumke P, Marko K, Lobsien D, Schulz S, Kahn T. RadLex – deutsche Version: ein radiologisches Lexikon zur Indexierung von Bild- und Befunddaten. *Fortschr Röntgenstr*. 2009;181:38–44.
7. RadLex Release Notes [Internet]. Google Docs. [cited 2020 Oct 17]. Available from: https://docs.google.com/document/d/10zRIBkXyj1eLt3LS_A7w3gSGRedXXoYvuchH6H4trCZY/edit?hl=en&pli=1&usp=embed_facebook
8. Kahn CE. Annotation of Figures from the Biomedical Imaging Literature. *Academic Radiology*. 2014;21:384–92.
9. Marwede D, Schulz T, Kahn T. Indexing Thoracic CT Reports Using a Preliminary Version of a Standardized Radiological Lexicon (RadLex). *J Digit Imaging*. 2008;21:363–70.
10. Bulu H, Sippo DA, Lee JM, Burnside ES, Rubin DL. Proposing New RadLex Terms by Analyzing Free-Text Mammography Reports. *J Digit Imaging*. 2018;31:596–603.
11. Deshpande P, Rasin A, Son J, Kim S, Brown E, Furst J, et al. Ontology-Based Radiology Teaching File Summarization, Coverage, and Integration. *J Digit Imaging* [Internet]. 2020 [cited 2020 Apr 16]; Available from: <http://link.springer.com/10.1007/s10278-020-00331-3>
12. Ostrom QT, Gittleman H, Fulop J, Liu M, Blanda R, Kromer C, et al. CBTRUS Statistical Report: Primary Brain and Central Nervous System Tumors Diagnosed in the United States in 2008-2012. *Neuro Oncol*. 2015;17:iv1–62.
13. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310:2191–4.
14. Frandsen S, Broholm H, Larsen VA, Grunnet K, Møller S, Poulsen HS, et al. Clinical Characteristics of Gliosarcoma and Outcomes From Standardized Treatment Relative to Conventional Glioblastoma. *Front Oncol*. 2019;9:1425.
15. Louis DN, Ohgaki H, Wiestler OD, Cavenee WK, Burger PC, Jouvet A, et al. The 2007 WHO Classification of Tumours of the Central Nervous System. *Acta Neuropathol*. 2007;114:97–109.
16. Ellingson BM, Bendszus M, Boxerman J, Barboriak D, Erickson BJ, Smits M, et al. Consensus recommendations for a standardized Brain Tumor Imaging Protocol in clinical trials. *Neuro Oncol*. 2015;17:1188–98.

17. Thust SC, Heiland S, Falini A, Jäger HR, Waldman AD, Sundgren PC, et al. Glioma imaging in Europe: A survey of 220 centres and recommendations for best clinical practice. *Eur Radiol.* 2018;28:3306–17.
18. RadLex Term Browser [Internet]. [cited 2020 Mar 28]. Available from: <http://radlex.org/>
19. Hong Y, Zhang J, Heilbrun ME, Kahn CE. Analysis of RadLex Coverage and Term Co-occurrence in Radiology Reporting Templates. *J Digit Imaging.* 2012;25:56–62.
20. Hazen R, Van Esbroeck AP, Mongkolwat P, Channin DS. Automatic Extraction of Concepts to Extend RadLex. *J Digit Imaging.* 2011;24:165–9.
21. Shore MW, Rubin DL, Kahn CE. Integration of Imaging Signs into RadLex. *J Digit Imaging.* 2012;25:50–5.
22. Raysi Dehcordi S, De Paulis D, Marzi S, Ricci A, Cimini A, Cifone MG, et al. Survival prognostic factors in patients with glioblastoma: our experience. *J Neurosurg Sci.* 2012;56:239–45.
23. Capellades J, Puig J, Domenech S, Pujol T, Oleaga L, Camins A, et al. Is a pretreatment radiological staging system feasible for suggesting the optimal extent of resection and predicting prognosis in glioblastoma? An observational study. *J Neurooncol.* 2018;137:367–77.
24. Heye AK, Culling RD, Valdés Hernández M del C, Thrippleton MJ, Wardlaw JM. Assessment of blood–brain barrier disruption using dynamic contrast-enhanced MRI. A systematic review. *NeuroImage: Clinical.* 2014;6:262–74.
25. Varatharaj A, Liljeroth M, Darekar A, Larsson HBW, Galea I, Cramer SP. Blood–brain barrier permeability measured using dynamic contrast-enhanced magnetic resonance imaging: a validation study. *J Physiol.* 2019;597:699–709.
26. Kazner E, Lanksch W, Steinhoff H, Wilske J. [Computerized axial tomography of the skull - diagnostic possibilities and clinical results (author’s transl)]. *Fortschr Neurol Psychiatr Grenzgeb.* 1975;43:487–574.
27. Fiegler W, Langer M, Scheer M, Kazner E. [Reversible computed tomographic changes following brain tumor irradiation induced by the “early-delayed reaction” after radiation]. *Radiologe.* 1986;26:206–9.
28. Duden | Wie kommt ein Wort in den Duden? [Internet]. [cited 2020 Nov 15]. Available from: https://www.duden.de/ueber_duden/wie-kommt-ein-wort-in-den-duden
29. VASARI Research Project - The Cancer Imaging Archive (TCIA) Public Access - Cancer Imaging Archive Wiki [Internet]. [cited 2021 Jul 12]. Available from: <https://wiki.cancerimagingarchive.net/display/Public/VASARI+Research+Project>
30. Siström CL, Langlotz CP. A framework for improving radiology reporting. *Journal of the American College of Radiology.* 2005;2:159–67.

31. Mamlouk MD, Chang PC, Saket RR. Contextual Radiology Reporting: A New Approach to Neuroradiology Structured Templates. AJNR Am J Neuroradiol. 2018;ajnr;ajnr.A5697v2.

Tables

Table 1_demographic and clinical data. This table presents demographic and clinical details of the analyzed patient cohort. Of note, all patients included in this study suffered from grade IV astrocytomas. SD=standard deviation.

	n=20
age at diagnosis (years±SD)	68.4±10.8
gender (male/female)	12 (60.0%)/8 (40.0%)
diagnosis_glioblastoma multiforme	19 (95.0%)
diagnosis_gliosarcoma	1 (5.0%)
surgery_resection	16 (80.0%)
surgery_biopsy	4 (20.0%)
symptomatic epilepsy	3 (15.0%)

Table 2_terms with non-verbatim/synonymous or multiple equivalent RadLex matches. This table shows all terms extracted from 20 consecutive glioblastoma multiforme MRI reports which have corresponding non-verbatim/synonymous or multiple equivalent RadLex entity matches.

term from radiology report	equivalent RadLex terms (RadLex ID)	frequency (n=20)
cella media	body of lateral ventricle (7125)	2 (10.0%)
contact	adjacent (5849)	2 (10.0%)
infiltration	invasive (5680) / tumor invasion of adjacent structure (39257)	2 (10.0%)
maximum expansion	maximum size (49883) / diameter (13432) + maximum (39164)	3 (15.0%)
narrow band	thin rim (43309)	1 (5.0%)
space occupying/mass effect	effect of mass on surrounding tissue (34379)	4 (20.0%)
speckled	punctate (5900) / patchy (5704)	1 (5.0%)
topographic relationship	adjacent (5849)	1 (5.0%)
weak/faint	minor (5691) / low (46059)	1 (5.0%)

Table 3_terms covered by a combination of RadLex entities. This table lists all terms gathered from twenty glioblastoma multiforme MRI reports that are appropriately described by means of a combination of two or more RadLex entities. ADC=apparent diffusion coefficient. * Commonly used German expression Mantelkante.

term from radiology report	equivalent combination of RadLex terms (RadLex ID)	frequency (n=20)
facilitated diffusion	ADC value (49527) + high (46060)	5 (25.0%)
frontobasal	frontal brain region (6391) + basal surface of cerebral hemisphere (21258)	1 (5.0%)
upper frontal region	superolateral face of cerebral hemisphere (20450) + frontal brain region (6391)	1 (5.0%)
internal tumor structure	structure (35808) + neoplasm (3957) or lesion (38780)	1 (5.0%)
irregular enhancement	irregular (5809) or heterogeneous (6060) + enhancement (34300)	1 (5.0%)
superomedial vertex of cerebral hemisphere*	junction of body part subdivisions (33017) + medial surface of cerebral hemisphere (21261) + superolateral face of cerebral hemisphere (20450)	2 (10.0%)
midline shift	midline (5826) + displacement (4751)	1 (5.0%)
normal perfusion pattern	perfusion imaging observation (38774) + normal (13173)	1 (5.0%)
paramedian	median (5846) + adjacent (5849)	1 (5.0%)
parietobasal	subdivision of basal surface of cerebral hemisphere (21264) + parietal brain region (6394)	1 (5.0%)
pericentral	central sulcus (6456) + adjacent (5849)	1 (5.0%)
perifocal edema	perilesional tissue characteristics (43362) + edema (4865)	14 (70.0%)
peritrigonal	collateral trigone (27786) or collateral trigone of lateral ventricle (7135) + adjacent (5849)	2 (10.0%)
physiologic diffusion pattern	diffusion (10374) + normal (13173)	3 (15.0%)
roof of lateral ventricle	wall of lateral ventricle (13822) + upper (46057)	1 (5.0%)
signs of malignancy	imaging observation (5) + suggestive (39481) + malignant (15655)	1 (5.0%)
subependymal	ependyma proper (19270) + adjacent (5849)	2 (10.0%)
sulcal effacement	subarachnoid space (7119) + reduced (49912) or narrow (10410)	2 (10.0%)
t1 hypointensity	t1 weighted (10794) + hypointense (35804)	1 (5.0%)
temporobasal	subdivision of basal surface of cerebral hemisphere (21264) + temporal brain region (6392)	1 (5.0%)

slight/faint
enhancement

Lesion enhancement (43365) or enhancement (34300) + minor
(5691) or low (46059)

3 (15.0%)

Supplementary Files

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