Quantitative MRI approach in the preoperative evaluation of a rare large-mass abdominal GIST tumor

Luca Basso[1]*, Vincenzo Alfano[2], Ciro Signoriello[1], Catello Longobardi[2], Massimo Picucci[2], Francesco Agozzino[2], Rosario Tortora[3], Andrea Biterski[1], Andrea Rinaldo[2], Umberto Atripaldi[2], Giovanni Moggio[2]

1. *Radiology Department, "P.O. San Paolo", ASL Napoli* 1;
2. *Radiology Department, "P.O. San Leonardo", ASL Napoli* 3 *Sud*;
3. *Radiology Department, AORN "A.Cardarelli", Naples*

* *Corresponding author.*
E-mail address: luca.basso1591@gmail.com

KeyWords:

GIST; Semi-automatic 3D segmentation; Volumetric analysis; Preoperative; MRI

Abstract

Gastrointestinal stromal tumors (GISTs) are rare cancers originating from the gastrointestinal tract's interstitial cells of Cajal. This study explores the utility of quantitative Magnetic Resonance Imaging (MRI), particularly volumetric lesion segmentation, in the preoperative evaluation of large-mass abdominal GISTs. MRI offers high-resolution imaging without ionizing radiation, which is crucial for oncology patients requiring repeated scans. Advanced semi-automatic segmentation techniques were employed in this study from different MRI sequences to enhance precision in tumor boundary delineation and volumetric analysis, and aid personalized surgical planning. In addition, this study demonstrates that using different clinical imaging protocols and comparing volumetric data from CT and various MRI sequences yields consistent results with minimal volumetric error. Finally, integrating MRI data into real-time surgical navigation systems underscored the synergy between radiology, surgical oncology, and computer science, improving tumor margin assessment and reducing recurrence risk. This approach highlights a pivotal shift towards technology-enhanced healthcare, promising better patient outcomes.

INTRODUCTION

A gastrointestinal stromal tumor (GIST) is an uncommon type of cancer that originates from cells in the walls of the gastrointestinal tract, specifically the interstitial cells of Cajal, which are part of the autonomic nervous system and help regulate muscle contractions in the digestive system. GISTs can occur anywhere along the gastrointestinal tract but are frequently found in the stomach or small intestine [1]. The cause of GISTs is usually linked to mutations in the KIT gene, which lead to uncontrolled cell proliferation. Most GISTs are sporadic, meaning they occur randomly and are not inherited, though there are rare familial forms of the disease associated with genetic syndromes such as neurofibromatosis type 1 or familial GIST syndrome [2]. Symptoms of GISTs can vary widely and may include abdominal pain, nausea, vomiting, loss of appetite, and blood in the stool. However, many GISTs are asymptomatic and may be discovered incidentally during procedures or imaging tests for other conditions [3].

Treatment options for GISTs include surgical removal of the tumor, which is often the primary treatment, especially if the tumor has not spread. In cases where the tumor is large or has spread, targeted therapies, particularly tyrosine kinase inhibitors like imatinib, are used [4]. These drugs target specific enzymes and pathways involved in the growth of cancer cells [5]. Overall, the prognosis for GISTs can vary based on factors such as tumor size, location, and response to treatment, with localized tumors generally having a better prognosis than those that have spread [6].

This article aims to show the potential of a quantitative MRI approach, as volumetric segmentation, in the preoperative evaluation of a rare large-mass abdominal GIST tumor. The utilization of Magnetic Resonance Imaging (MRI) emerges as a keystone in this process, primarily due to its inherent advantage of acquiring high-resolution images without exposure to ionizing radiation, a significant concern in repeated imaging scenarios common in oncology [7]. The emphasis on MRI underscores a crucial shift towards safer imaging modalities that do not compromise on the quality and detail necessary for surgical precision.

Moreover, the development and application of automatic and semi-automatic segmentation techniques represent a leap forward in medical imaging. These methods not only expedite the process of delineating tumor boundaries but also improve the accuracy and repeatability of volumetric analyses essential for evaluating tumor size and response to treatment. The integration of automatic and semi-automatic segmentation tools in MRI leverages the power of artificial intelligence and machine learning, offering a synergistic approach that combines the irreplaceable expertise of radiologists with the computational efficiency of algorithms. the advantages are:

JAHC
OFFICIAL JOURNAL OF TSRM PSTRP
JOURNAL OF ADVANCED HEALTH CARE

RESEARCH ARTICLE

Citation:

L. Basso et al.

"Quantitative MRI approach in the preoperative evaluation of a rare large-mass abdominal GIST tumor"

JAHC 6:3 2024

Received: 08/06/2024
Revised: 13/06/2024
Accepted: 14/06/2024
Published: 19/06/2024

1. Improved Precision in Surgery: Enhanced MRI volumes provide surgeons with more detailed and accurate images of tumors, including their size, shape, and location relative to critical anatomical structures. This precision is particularly crucial for complex cases where the tumor is located near vital organs or within intricate networks of blood vessels.
2. Personalized Surgical Planning: The detailed visualization made possible by these large-volume MRIs allows for more personalized surgical planning. Surgeons can tailor their approach based on the specific characteristics of the tumor and surrounding tissues, potentially reducing the likelihood of complications, and improving outcomes.
3. Real-time Navigation During Surgery: Some advanced setups integrate these MRI data into surgical navigation systems, providing real-time guidance during operations.
4. Better Assessment of Tumor Margins: Accurately determining tumor margins is important for successful oncological surgery. High-resolution MRI scans help in defining these margins more clearly, which is key for achieving complete resection and minimizing the risk of recurrence.

The importance of this interdisciplinary approach, merging radiology, surgical oncology, and computer science, cannot be overstated. It not only represents a significant step forward in the application of medical imaging for pre-surgical planning but also exemplifies the broader potential of technology-enhanced healthcare in improving patient outcomes [8] [9] [10].

MATERIALS AND METHODS

A 72 years-old male patient arrived at the Emergency Department at San Leonardo Hospital (Castellammare di Stabia, Italy) with an untreatable abdomen, abdominal pain with a relevant mass on palpation, nausea, and vomiting. Imaging, laboratory examinations, and histopathology records were collected. Informed consent was obtained for the examinations. The patient undergoes firstly an ultrasound examination that shows a hypoechoic area relative to surrounding structures with a prominent blood supply, hypervascular on Doppler imaging.

Imaging Protocol and Data Analysis

MRI examination was performed using a Magnetom Sola 1.5 T scanner (Siemens Healthcare, Erlangen, Germany), with a 16-channel flex phased-array body coil and reviewed by a ten-year expert radiologist. A standard clinical abdominal MRI protocol was employed, consisting of:
- coronal and axial T2-weighted Half-Fourier Acquisition Single-shot Turbo spin Echo imaging (HASTE), voxel size 1.2×1.2×4 mm3, Field of View (FOV) 195×320 mm, TR/TE = 1800/95 ms;
- axial T1 Dual-echo Fast Spin Echo, voxel size 1.2×1.2×3 mm3, FOV 195×320 mm, TR/TE = 6.7/2.4 ms;
- axial T2-Haste with fat saturation, 1.2×1.2×4 mm3, Field of View (FOV) 195×320 mm, TR/TE = 1800/97 ms;
- axial diffusion-weighted imaging (DWI) with apparent diffusion coefficient map, voxel size 1.2×1.2×3 mm3, FOV 195×320 mm, TR/TE = 4000/60 ms;
- coronal T2-True Fast Imaging with Steady State Precession (TrueFISP), 0.8×0.8×4 mm3, Field of View (FOV) 256×256 mm, TR/TE = 390/2.1 ms;
- three plane isotropic 1 mm post-contrast DIXON Fat-Suppressed Volumetric Interpolated Breath-hold Examination (VIBE).

To obtain reliable volumetric quantitative data, different acquired MRI sequences were processed and compared. In addition to axial T2-HASTE segmentation (considered as a standard reference) (Figure 1), the same post-processing method was applied to segment the lesion from axial T1 dual-echo, coronal True-Fisp, and coronal post-contrast T1-dixon with fat saturation (Figure 2). These comparisons were made possible due to the capabilities of the post-processing software, which can generate volumetric data that account for the varying voxel sizes across different sequences while ensuring the accuracy of the volume in each case.
The volumetric image analysis of the abdominal mass was determined using ITK-SNAP software [11] through a semi-automatic 3D segmentation technique with an automated process that uses signal intensity thresholds to delineate the boundaries of the lesion within the imaging data. This initial segmentation acts as a rough outline based on predefined intensity criteria that differentiate the target lesion from the surrounding tissues.
Once this automated step is completed, the segmentation is refined manually. A second radiologist, with nine-years experience in body-MRI, reviewed and adjusted the boundaries of the segmentation in the three orthogonal planes. These manual corrections are critical for accounting for variations in lesion shape, size, and boundary clarity that automated methods may not fully capture. Subsequently, in order to compare the lesion volume through different modalities an additional segmentation was performed from the CT scan (Figure 3).

Biopsy Protocol & Immunohistochemistry

The patient undergoes preparatory 8h fasting, to reduce gastrointestinal content and potential complications. Following aseptic preparation of the skin and application of local anesthesia to minimize nociceptive stimuli, real-time ultrasound visualization guides the insertion of a core 14-gauge needle biopsy instrument through the dermal layers into the targeted lesion. This approach mitigates collateral tissue damage and enhances the accuracy of the biopsy. Two cores of 1.7 and 1.4 millimeters were extracted to increase diagnostic yield and mitigate sampling error. Each piece of tissue was

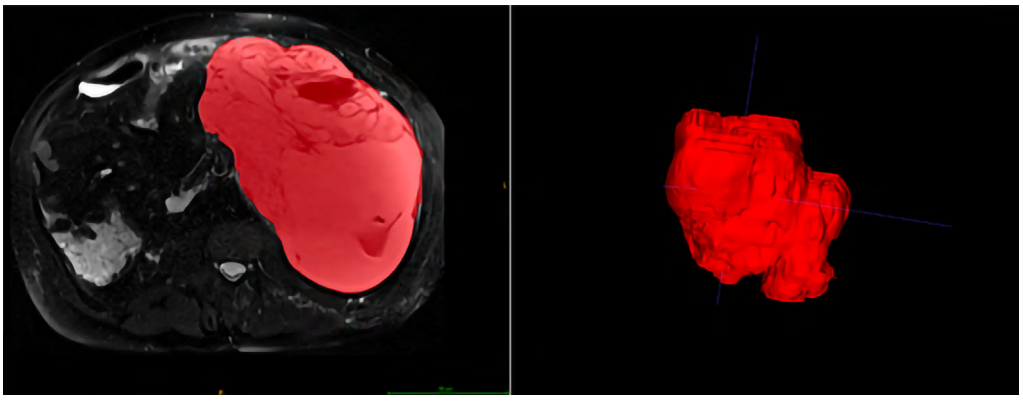

Figure 1. *Left: Axial T2-HASTE view of the lesion, with the lesion's mask highlighted in red. Right: the 3D models of the pathological mass tissue are displayed.*

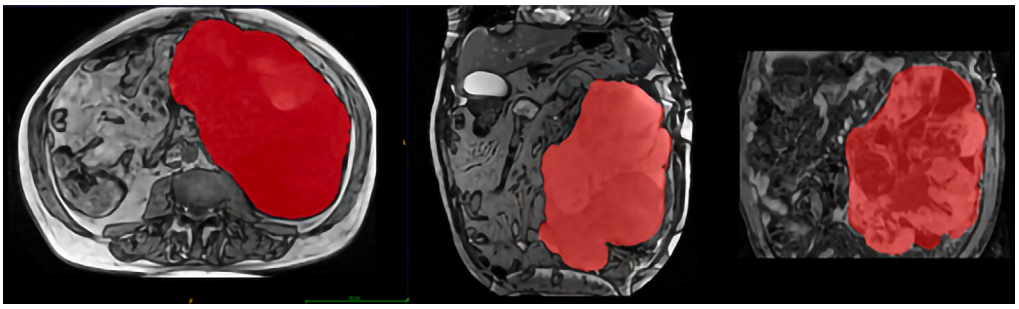

Figure 2. *Left: Axial T1 dual-echo Fast Spin Echo and corresponding segmentation mask. Center: Coronal TrueFISP and segmentation mask. Right: Coronal post-contrast T1 Dixon sequence and corresponding segmentation mask.*

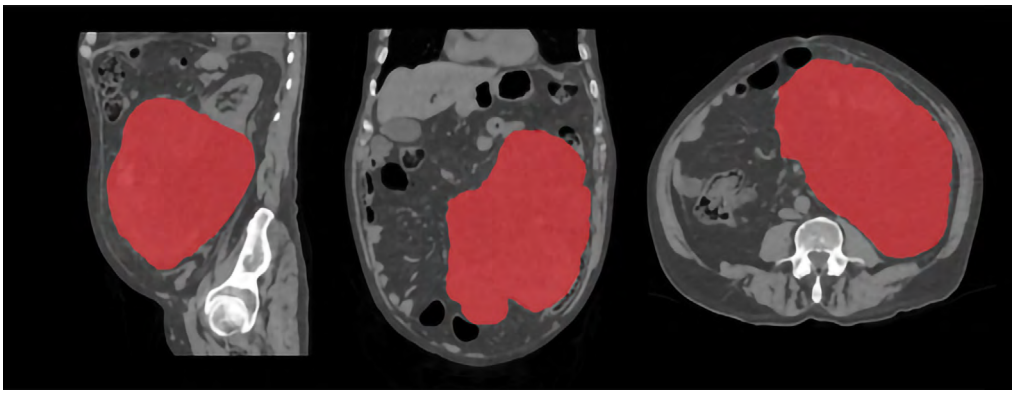

Figure 3. *CT scan and segmentation mask in red. From left to right, the three scan planes views sagittal, coronal, and axial.*

promptly fixed in 10% neutral buffered formalin, preserving cellular morphology for subsequent histopathological evaluation.

In the pathology laboratory, the tissues undergo dehydration, clearing, and paraffin embedding. Microtome-sectioned slices are then stained with Hematoxylin and Eosin for morphological assessment. Immunohistochemical analysis employing antibodies against CD117 (c-Kit) and DOG1 is pivotal, as these markers are highly indicative of GISTs (Figure 4) [12].

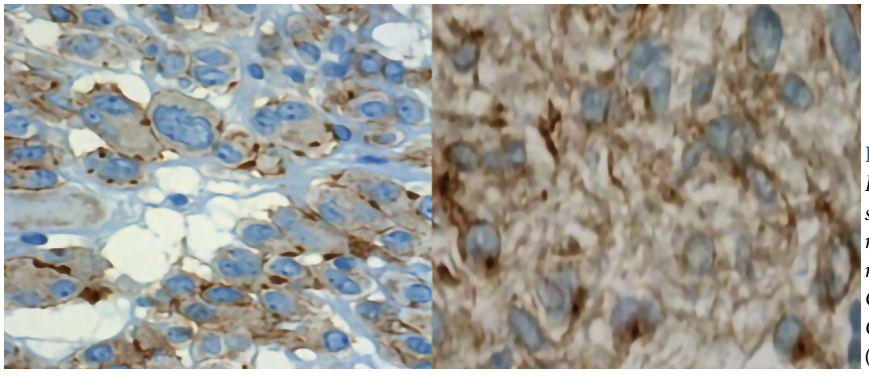

Figure 4.
Left: DOG1 immunostaining shows an epithelioid GIST with membrane and dot-like paramembrane staining. Right: CD117 immunostaining of GIST reveals a paranuclear (Golgi) pattern.

JAHC
JOURNAL OF ADVANCED HEALTH CARE
OFFICIAL JOURNAL OF TSRM PSTRP

RESEARCH ARTICLE

Citation:
L. Basso et al.
"Quantitative MRI approach in the preoperative evaluation of a rare large-mass abdominal GIST tumor"
JAHC 6:3 2024

Received: 08/06/2024
Revised: 13/06/2024
Accepted: 14/06/2024
Published: 19/06/2024

RESULTS

The MRI examination of the abdomen reveals a large, lobulated, multi-segmented mass in the left abdominal spaces, measuring 134 x 232 x 236 mm (AP x Transverse x CC). The mass has well-defined margins and an inhomogeneous content due to the presence of both solid and fluid-suprafluid components, likely including intralesional blood. The solid portions, primarily located caudally, along with the lesion walls, exhibit contrast enhancement and restricted diffusion. The mass lacks a clear plane of cleavage with some small bowel loops in the right iliac fossa and the descending colon, and it contacts the left lower renal pole, which is displaced cranially. The primary hypothesis is that this lesion is a GIST.

The biopsy examination shows positive immunoreactivity and corroborates the presence of a GIST, facilitating further oncological management based on molecular and morphological characteristics observed [13] [14].

The volume extracted from CT image processing was 3913000 mm3. Table 1 presents the values of different volumes detected by MRI sequences and the relative error in percent calculated by comparing the measured value with the CT reference value.

MRI Sequence	*Volume (mm3)*	*Relative Error (%)*
Axial T2-Haste with fat saturation	3875000	0,97
Axial T1 Dual-echo Fast Spin Echo	3824000	2,27
Coronal TrueFISP	3862000	1,30
Coronal Post-contrast T1 Dixon	3863000	1,27

Table 1.
***Left*:** *The MRI sequences used for post-processing to calculate the lesion volume.*
***Center*:** *The volumes obtained from the segmentation process, expressed in cubic millimeters, are compared to evaluate the effectiveness of different sequences in volume calculation.*
***Right*:** *Relative error in percentage to CT segmentation volume.*

DISCUSSION

In our study, a large lobulated mass with well-defined margins and heterogeneous content was identified, exhibiting both solid and fluid components. The volumetric measurements obtained from MRI scans show a high degree of concordance between the volume measured with different MR sequences. In addition, when comparing the same MRI data with volumetric data derived from CT image processing, taken as reference data, we obtain a very low degree of relative error (less than 2.5%). This consistency is maintained despite potential variations in lesion volumes due to differing depths of apnea.

The findings from this study underscore the significant potential of quantitative MRI, specifically volumetric segmentation, in the preoperative evaluation of rare, large-mass abdominal GIST tumors [15]. Utilizing MRI for its high-resolution imaging capabilities without ionizing radiation proves particularly advantageous in oncology, where repeated imaging is often required. The application of semi-automatic segmentation techniques enhances the precision and repeatability of volumetric analyses, crucial for accurate tumor delineation and assessment [16]. The advanced imaging techniques allowed for detailed visualization and informed surgical planning, demonstrating improved precision in delineating tumor boundaries and enhancing personalized surgical approaches. Furthermore, the integration of MRI data into real-time surgical navigation systems exemplifies the interdisciplinary synergy between radiology and surgical oncology staff, promising better assessment of tumor margins and potentially reducing recurrence rates. This study also highlights how the use of a clinical imaging protocol, developed with appropriate software and techniques, can accurately calculate the volume of the lesion. Specifically, it becomes evident that by comparing the volumetric data obtained from different MRI sequences, also acquired with different techniques to reduce motion artifacts caused by the patient's breathing, and with varying slice thicknesses, the data is consistent. Additionally, By comparing the data obtained from MRI scans with those from a CT scan acquired with a 1.25 mm slice thickness in a single apnea, we achieve a result with a relative error of less than 2.5%. This level of accuracy is entirely acceptable and justifiable, given the inherent variability in reproducing the same inspiratory apnea each time. The same abdominal organ compression, caused by the lowering of the diaphragm, cannot be consistently replicated [17]. The combined approach of semi-automated segmentation and expert radiologist review ensures optimal accuracy in tumor volume estimation, critical for effective surgical intervention [18]. This methodology not only enhances the surgeon's ability to plan and execute complex procedures but also signifies a step forward in leveraging advanced imaging technologies to improve patient outcomes

in the management of GISTs. Despite the promising results, several limitations of this study must be acknowledged. First, the reliance on a single patient's data limits the generalizability of the findings. Larger studies are needed to validate the efficacy of the quantitative MRI approach in diverse patient populations. Second, the high-resolution imaging protocols used, while advantageous, may not be universally available due to the high cost and need for specialized equipment, potentially limiting widespread application. Additionally, the manual refinement of segmentation, although crucial for accuracy, is time-consuming and heavily dependent on the expertise of the radiologist, introducing a potential for variability and human error. Addressing these limitations in future research will be crucial to enhance the applicability and reliability of this imaging approach in the preoperative evaluation of GISTs and other complex tumors. In particular, the integration of these techniques into routine clinical practice could revolutionize preoperative planning, offering a robust framework for tackling similarly complex oncological cases in the future.

REFERENCES

1. *Parab, T. M., DeRogatis, M. J., Boaz, A. M., Grasso, S. A., Issack, P. S., Duarte, D. A., Urayeneza, O., Vahdat, S., Qiao, J. H., & Hinika, G. S.* (2019). *Gastrointestinal stromal tumors: a comprehensive review. Journal of gastrointestinal oncology*, 10(1), 144–154. *https://doi.org/10.21037/jgo.2018.08.20*
2. *Cappellani, A., Piccolo, G., Cardì, F., Cavallaro, A., Lo Menzo, E., Cavallaro, V., Zanghì, A., Di Vita, M., & Berretta, M.* (2013). *Giant gastrointestinal stromal tumor (GIST) of the stomach cause of high bowel obstruction: surgical management. World journal of surgical oncology*, 11, 172. *https://doi.org/10.1186/1477-7819-11-172*
3. *Gheorghe, M., Predescu, D., Iosif, C., Ardeleanu, C., Băcanu, F., & Constantinoiu, S.* (2014). *Clinical and therapeutic considerations of GIST. Journal of medicine and life*, 7(2), 139–149.
4. *Lopes, L. F., & Bacchi, C. E.* (2010). *Imatinib treatment for gastrointestinal stromal tumour (GIST). Journal of cellular and molecular medicine*, 14(1-2), 42–50. *https://doi.org/10.1111/j.1582-4934.2009.00983.x*
5. *Patil, A., Haval, S., Nichkaode, P., & Dwivedi, D.* (2023). *Gastrointestinal Stromal Tumor: A Clinicopathological Study and Management. Cureus*, 15(11), *e*49469. *https://doi.org/10.7759/cureus.49469*
6. *Parab, T. M., DeRogatis, M. J., Boaz, A. M., Grasso, S. A., Issack, P. S., Duarte, D. A., Urayeneza, O., Vahdat, S., Qiao, J. H., & Hinika, G. S.* (2019). *Gastrointestinal stromal tumors: a comprehensive review. Journal of gastrointestinal oncology*, 10(1), 144–154. *https://doi.org/10.21037/jgo.2018.08.20*
7. *Alfano, V., Granato, G., Mascolo, A., Tortora, S., Basso, L., Farriciello, A., Moggio, G.* (2024). *Advanced neuroimaging techniques in the clinical routine: A comprehensive MRI case study. Journal of Advanced Health Care*, 6(2). *https://doi.org/10.36017/jahc202462336*
8. *Dell'Oglio, P., Mazzone, E., Buckle, T., Maurer, T., Navab, N., van Oosterom, M. N., Schilling, C., Witjes, M. J., Vahrmeijer, A. L., Klode, J., Vojnovic, B., Mottrie, A., van der Poel, H. G., Hamdy, F., & van Leeuwen, F. W.* (2022). *Precision surgery: the role of intra-operative real-time image guidance - outcomes from a multidisciplinary European consensus conference. American journal of nuclear medicine and molecular imaging*, 12(2), 74–80.
9. *Singh, G. D., & Singh, M.* (2021). *Virtual Surgical Planning: Modeling from the Present to the Future. Journal of clinical medicine*, 10(23), 5655. *https://doi.org/10.3390/jcm10235655*
10. *Basso, L., Baldi, D., Mannelli, L., Cavaliere, C., Salvatore, M., & Brancato, V.* (2021). *Investigating Dual-Energy CT Post-Contrast Phases for Liver Iron Quantification: A Preliminary Study. Dose-response: a publication of International Hormesis Society*, 19(2), 15593258211011359. *https://doi.org/10.1177/15593258211011359*
11. *Yushkevich PA, Piven J, Hazlett HC, Smith RG, Ho S, Gee JC, Gerig G. User-guided 3D active contour segmentation of anatomical structures: significantly improved efficiency and reliability. Neuroimage.* 2006 *Jul* 1;31(3):1116-28. *doi*: 10.1016/*j.neuroimage*.2006.01.015.
12. *Galatola, R., Romeo, V., Simeoli, C., Guadagno, E., De Rosa, I., Basso, L., Mainolfi, C., Klain, M., Nicolai, E., Colao, A., Maurea, S., & Salvatore, M.* (2021). *Characterization with hybrid imaging of cystic pheochromocytomas: correlation with pathology. Quantitative imaging in medicine and surgery*, 11(2), 862–869. *https://doi.org/10.21037/qims-20-490*
13. *Miettinen, M., Sobin, L. H., & Sarlomo-Rikala, M.* (2000). *Immunohistochemical spectrum of GISTs at different sites and their differential diagnosis with a reference to CD*117 (*KIT*). *Modern pathology : an official journal of the United States and Canadian Academy of Pathology, Inc*, 13(10), 1134–1142. *https://doi.org/10.1038/modpathol.3880210*
14. *Appat, T., Paruthy, S. B., Mohan, S. K., Singh, K., & Das, A.* (2022). *DOG1-Positive Extragastrointestinal Stromal Tumor Presenting As Large Abdomino-Pelvic Mass: A Case Report. Cureus*, 14(11), *e*31670. *https://doi.org/10.7759/cureus.31670*
15. *Inoue, A., Ota, S., Yamasaki, M., Batsaikhan, B., Furukawa, A., & Watanabe, Y.* (2022). *Gastrointestinal stromal tumors: a comprehensive radiological review. Japanese journal of radiology*, 40(11), 1105–1120. *https://doi.org/10.1007/s11604-022-01305-x*
16. *Luna, A., Pahwa, S., Bonini, C., Alcalá-Mata, L., Wright, K. L., & Gulani, V.* (2016). *Multiparametric MR Imaging in Abdominal Malignancies. Magnetic resonance imaging clinics of North America*, 24(1), 157–186. *https://doi.org/10.1016/j.mric.2015.08.005*
17. *Brancato, V., Della Pepa, G., Bozzetto, L., Vitale, M., Annuzzi, G., Basso, L., Cavaliere, C., Salvatore, M., Rivellese, A. A., & Monti, S.* (2022). *Evaluation of a Whole-Liver Dixon-Based MRI Approach for Quantification of Liver Fat in Patients with Type 2 Diabetes Treated with Two Isocaloric Different Diets. Diagnostics (Basel, Switzerland)*, 12(2), 514. *https://doi.org/10.3390/diagnostics12020514*

JAHC JOURNAL OF ADVANCED HEALTH CARE
OFFICIAL JOURNAL OF TSRM PSTRP

RESEARCH ARTICLE

Citation:

L. Basso et al.

"Quantitative MRI approach in the preoperative evaluation of a rare large-mass abdominal GIST tumor"

JAHC 6:3 2024

Received: 08/06/2024
Revised: 13/06/2024
Accepted: 14/06/2024
Published: 19/06/2024

18. *Baldi, D., Basso, L., Nele, G., Federico, G., Antonucci, G. W., Salvatore, M., & Cavaliere, C.* (2021). *Rhinoplasty Pre-Surgery Models by Using Low-Dose Computed Tomography, Magnetic Resonance Imaging, and 3D Printing. Dose-response : a publication of International Hormesis Society*, 19(4), 15593258211060950. *https://doi.org/*10.1177/15593258211060950

Author Contributions:
Conceptualization, L.B., and V.A.; methodology, B.L., V.A., C.L., M.P; formal analysis, V.A., L.B., R.T.; writing—original draft preparation, L.B.; writing—review and editing, C.S., F.A., A.B., A.R., U.A.; supervision, G.M. All authors have read and agreed to the published version of the manuscript. Authorship must be limited to those who have contributed substantially to the work reported.

Institutional Review Board Statement:
The study was conducted in accordance with the Declaration of Helsinki and Informed consent was obtained from all subjects involved in the study.
Data Availability Statement: Research data can be shared with researchers upon reasonable request.

Conflicts of Interest:
The authors declare no conflict of interest.

RESEARCH ARTICLE
JAHC | JOURNAL OF ADVANCED HEALTH CARE
OFFICIAL JOURNAL OF TSRM PSTRP