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Tumour Detection in Fabricated Gelatin Brain Phantom Model Using Ultra Wide Band Planner Antenna

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ABSTRACT: This paper describes the design of an antenna and the development of a brain phantom model to validate the simulation results. The fabricated design of the phantom is interfaced with fabricated antenna, and the tumour in the fabricated phantom brain model is detected by return loss variation of the transmitted and reflected signals. Antennas are designed at the 2.45 GHz ISM (Industrial Science Medical) band and 5.8 GHz, and the lengths and widths for rectangular microstrip patch antenna (RMPA) have been calculated from the standard design equations. Different types of defects are applied in the front plane and ground plane of the antenna. Defect Ground Structures (DGSs) are applied to make the antenna ultra-wideband (UWB), because UWB is the basic requirement of antenna used in tumour detection applications. The design of gelatine brain phantom models with tumour and tumour-free is described. Finally, the brain phantom design is interfaced to each deigned antenna. The tumour in brain is detected by variations in the incident and reflected wave reflection loss parameter.

1. INTRODUCTION

Tumour detection in the body parts of the human is a challenging task to doctors, because of the disadvantage included in the repetition of these available tests. This paper describes the fabrication of the gelatine-based brain phantom model with and without tumour. The design of a Planner Rectangular Microstrip Patch antenna with a Defect Ground Structure has been discussed for ultra-wideband (UWB) application. Finally, these designed and fabricated antennas were interfaced to the developed model with and without tumour and tumour in model brain detected by the variation of scattering parameter in input and reflected wave. Although various techniques are available to identify tumours in the brain, such as magnetic resonance imaging (MRI), computed tomography (CT scan), these procedures are invasive, meaning that they have the disadvantage of direct exposure to X-rays or magnetic field. Their repetition may have the negative impacts of radiations. Non-Invasive Technique to detect the tumour in brain is Microwave Imaging. Detection is based on analysing the scattering parameter with and without tumour. The antenna used in this method is a novel ultra-wideband antenna operating in frequency range of 2.6 GHz to 13.1 GHz, and smoothing 'mslowess' procedure is applied to remove the noise content in the result [2–5]. Radiation properties of Vivaldi antenna are interfaced with human head model for brain cancer detection. Brain phantom model is designed with its dielectric properties. Higher value of Specific Absorption Rate (SAR) in human head model with tumour shows the presence of tumour, and feko software is used for simulation [6]. In [7], a UWB antenna with the dimension of $329.25 \times 153 \times 1.6$ mm is designed which operates at the frequency of 100 MHz to 1.4 GHz. This antenna is designed with an FR4 substrate and matched with brain tissues, and finally radiation is analysed with and without tumour in brain phantom model. A new holography microwave imaging technique has been proposed to detect the brain cancer in [8]. Aperture synthesis imaging and holographic microwave imaging have been proposed for a realistic three-dimensional head model with different elements of brain, i.e., skin, fat, skull, gray matter, white matter, and cerebrospinal fluid (CSF). The homographic area is developed using MATLAB (Matrix Laboratory) software, and matching solution is used between head and antennas. Further, Small Stroke area of 5 mm is detected using HMIA (Homographic imaging analysis) approach. Microwave tomography has been proposed for breast cancer and brain tumour detection. Algorithm of structural inversion is applied to achieve real MRI (Magnetic resonance imaging) phantom images [9]. An array of UWB Vivaldi antenna for microwave imaging is designed, and a tumour of 5 mm size is detected [10]. Four different layers of brain phantom model are designed with CST microwave studio. Input signal is applied to the brain phantom model, and reflected signal has been analysed to detect the tumour. This method reduces the noise, and various methods are used to match actual and detected tumours.

Tapered Compact microstrip antenna for brain tumour detection is proposed in [11]. The antenna is placed in the liquid of high coupling capacity which is required for high-level signal penetration into the antenna in the brain and is tested using a suitable model of head. The antenna having a substrate size of 24×24 mm on RT6010 (RT duroid) operates efficiently from 1 GHz to more than 4 GHz. In [12], a fabricated array of three smart antennas for brain tumour detection is discussed, and a brain model having different layers with the radius of 5 mm tu-

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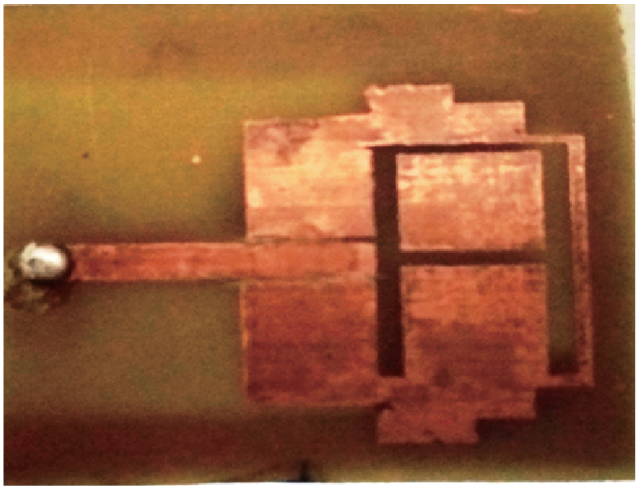

FIGURE 1. Fabricated RMPA ultra-wide band Design-1 front planes.

FIGURE 2. Fabricated RMPA ultra-wide band Design-1 ground plane.

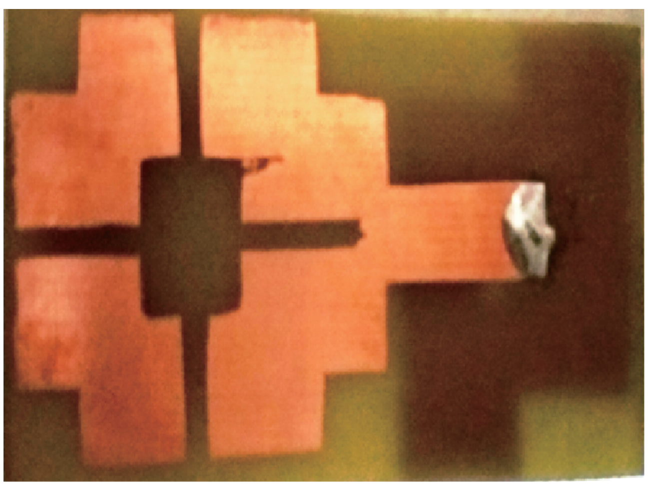

FIGURE 3. Fabricated ultra-wideband Design-2 front plane.

FIGURE 4. Fabricated ultra-wideband Design-2 ground plane.

mour is modelled. Input signal is applied to the brain having tumours, and signal reflected from tumours has been studied. The analysis of reflected signal shows that an array of antenna can be used to detect the brain tumours.

2. ANTENNA DESIGNS

The antenna design process initially requires exporting the software files from the simulation software. Export .dxf file of CST simulation software 2014 antenna design and export data printed on oil paper. The antenna printed on a paper is applied to the PCB board with an FR4 substrate, and then the antenna is printed on the PCB by the photolithography process. Etching is the process of removing the desired metal from the front plane and ground plane of the PCB. Fecl3 (Iron chloride) solution is used in the etching process. After the material has been scraped from the front of the antenna and from the ground plane, the final process is to implant the coaxial port into the antenna. Drilling is used to drill holes on the PCB, and the coaxial ports are connected by electronic soldering. Finally, all the designs were made with the process outlined above, and all the front antennas and ground planes are shown in Figs. 1–5. All antennas' basic dimensions were calculated from the antenna design equation given in C.balanies [1]. All antennas slot DGS pattern dimensions have been calculated by hit and trial method for the lowest reflection coefficient on CST Simulation software.

3. SIMULATED AND MEASURED RESULTS

The comparison of simulated reflection parameter with practical reflection parameter of all designs is given in Fig. 6.

Practical setup of the fabricated T-shaped slotted planner antenna with vector network analyser is shown in Fig. 7, and Fig. 8 shows the comparison of simulated and practical return losses of the fabricated T-shaped slotted RMPA.

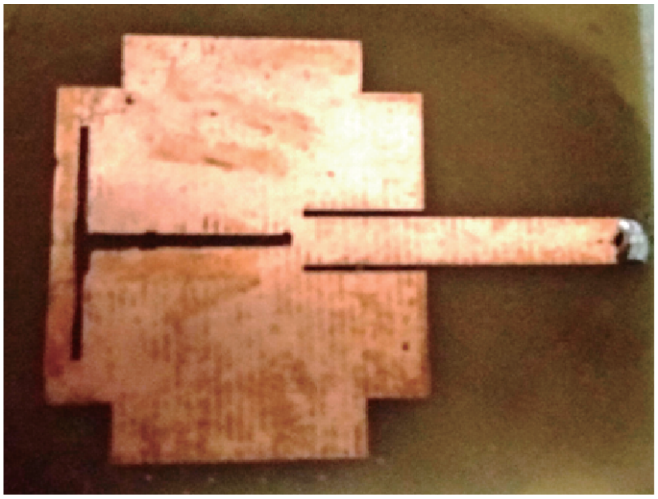

FIGURE 5. Fabricated T-shaped slotted RMPA front plane.

FIGURE 6. Fabricated T-shaped slotted ground plane.

FIGURE 7. Practical setup of measurement of T-shaped slotted planner antenna.

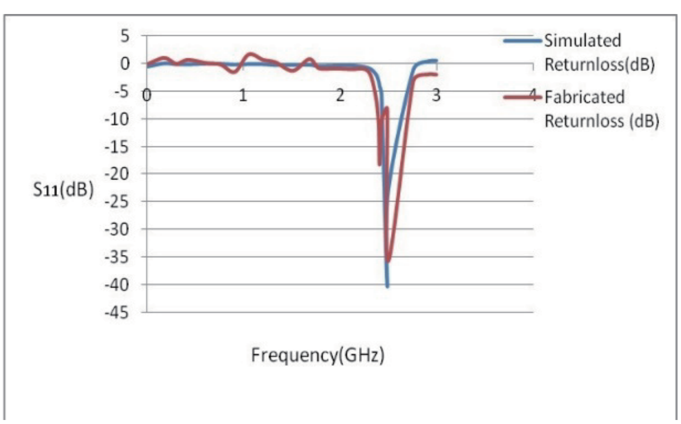

FIGURE 8. Simulated v/s practical return-loss of T-shaped slotted planner antenna.

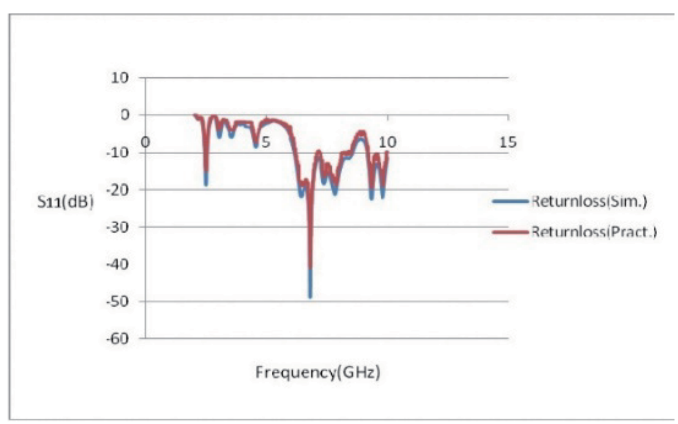

FIGURE 9. Simulated v/s practical results of fabricated antenna Design-1.

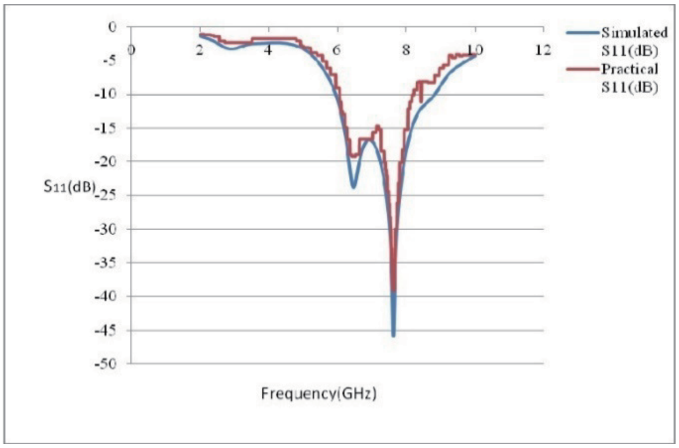

FIGURE 10. Simulated v/s practical results of fabricated antenna Design-2.

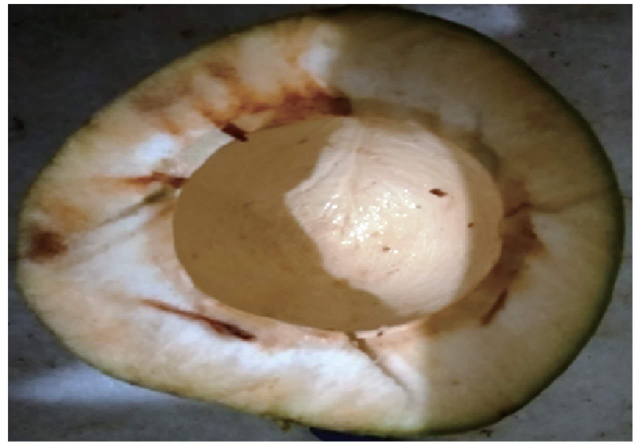

FIGURE 11. Brain phantom model coconut mould.

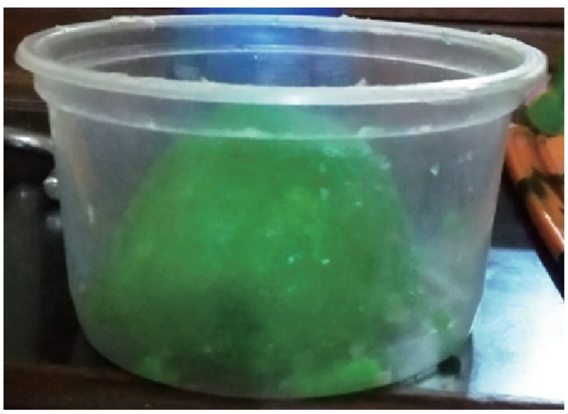

FIGURE 12. Fabricated brain phantom model.

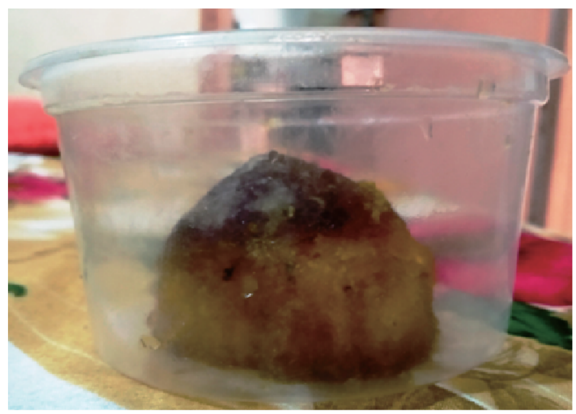

FIGURE 13. Fabricated brain phantom model with tumour.

In Fig. 8, simulated results show that the maximum peak of return loss at 2.49 GHz is 39.8 dB, and the fabricated antenna shows that the maximum peak of losses at 2.5 GHz is -35 dB. Fig. 9 shows the simulated v/s practical return-loss of ultra-wideband antenna Design-1, and it shows that the maximum simulated result peak at 6.8 GHz is -48.87 dB and fabricated results -40.87 dB at 6.8 GHz.

Fig. 10 shows the simulated v/s practical results of S_{11} for the ultra-wideband fabricated antenna Design-2. Fig. 10 shows that the maximum simulated peak at 7.62 GHz is -45.76 dB, and maximum fabricated antenna peak at 7.62 GHz is -39.12 dB.

4. FABRICATION OF BRAIN PHANTOM MODEL WITH AND WITHOUT TUMOUR

The brain phantom model was created using gelatine powder as the basic ingredient because gelatine has the same dielectric properties as the brain layer [13]. Add 20 percent boiled water in a 90 gram powder gelatine package and mix, then add one glass of hot milk and 1 teaspoon coconut oil and mix. Mix the entire mixture and pour it into a coconut mould to get a brain like shape. Pour the mixture into the coconut mould and freeze for 6 to 7 hours, and after freezing remove the brain model from the coconut mould and put it in a plastic container. The obtained brain model is shown in Fig. 11 [14].

5. BRAIN PHANTOM MODEL WITH TUMOUR

For the development of brain phantom model with tumour, initially the gelatin brain phantom model is developed by taking the gelatin powder 90 gm, adding 40% boiled water into it then add 1 cup cold water in it. After some time about 1 minute, 60 ml hydrogen peroxide is added for the development of tumour into it. The whole material is poured into the coconut mould, then it is frozen for about 6–7 hours. Finally, the developed brain phantom model with tumour is extracted from the coconut mould. The fabricated gelatin brain phantom models without and with tumour are shown in Fig. 12 and Fig. 13, respectively.

FIGURE 14. Experimental setup of brain phantom model with antenna.

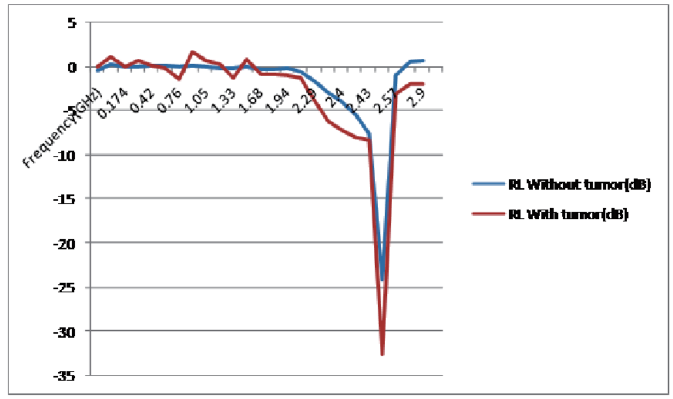

FIGURE 15. Return-loss of brain phantom model with and without tumour.

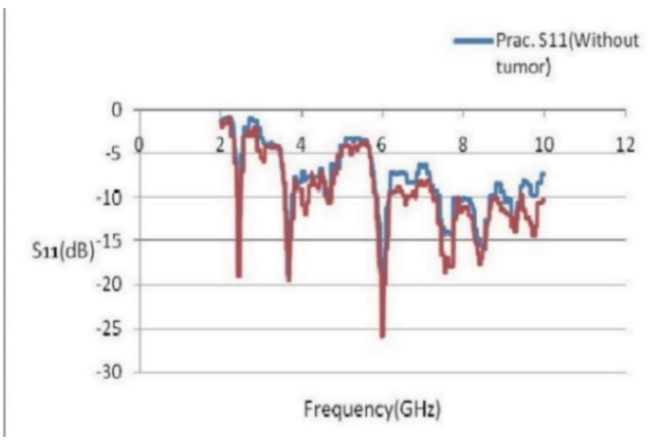

FIGURE 16. Returnloss v/s frequency graph of fabricated Design-1 with brain phantom model.

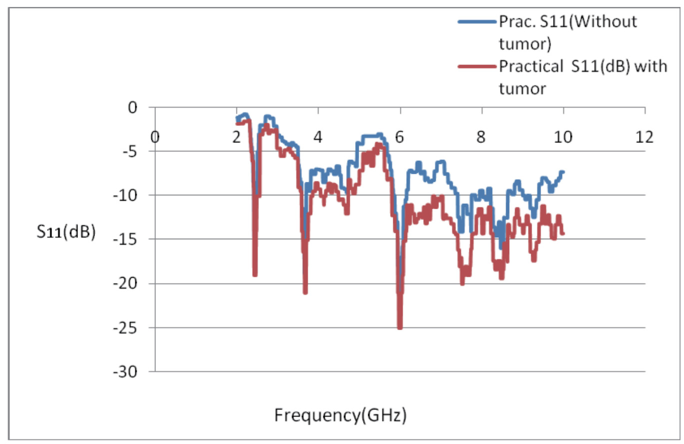

FIGURE 17. Returnloss v/s frequency graph of fabricated antenna Design-2 with and without tumour.

6. INTERFACING OF BRAIN PHANTOM MODEL WITH FABRICATED ANTENNAS

In this section, the developed brain phantom model is interfaced with all fabricated antennas. Tumour in the developed brain phantom model has been detected by the variation in the performance parameter return loss of antenna. Experimental setup of brain phantom model with vector network analyser is shown in Fig. 14.

Fig. 15 shows the comparison of return losses of brain phantom model with and without tumour with T-shaped slotted planer antenna.

The antenna without tumour shows the maximum peak of return loss of 24.23 dB and that with tumour of 32.64 dB, respectively, hence it is verified that the losses decreased in brain with tumour, and it shows the presence of tumour.

Fig. 16 shows the return-loss v/s frequency graph of brain phantom model with and without tumour of Design-1.

Fig. 16 shows that the maximum peak without tumour is −21 dB at 5.98 GHz and −25 dB at 5.98 GHz with tumour, and the variation in maximum peak of return loss shows the presence of tumour. Fig. 17 shows the return loss v/s frequency graph of fabricated antenna Design-2 with developed brain phantom model with and without tumour.

It shows that the maximum peak at 5.97 GHz is −18 dB without tumour, and with tumour it shows that the maximum peak at 5.97 GHz is −21 dB. The variation in return loss with and without tumour shows the presence of tumour.

7. CONCLUSION

In this paper, a manufacturing method for antennas is first described. Different images are used to show various antenna design types. For every manufactured antenna, actual reflection coefficient and simulated reflection coefficient results are provided. Gelatine brain phantom model design with and without tumour has been discussed. Finally, each antenna design is interfaced with the brain phantom design. The variations in antenna return loss is used to identify brain cancers.

REFERENCES

[1] Balanis, C. A., *Antenna Theory*, Wiley, 1997.

[2] Deschamps, G. A., "Microstrip microwave antennas," in *Proceedings of the Third Symposium on the USAF Antenna Research and Development Program*, 18–22, Oct. 1953.

[3] David, M. P. and H. S. Daniel, *Microstrip Antennas: The analysis and Design of Microstrip Antennas and Arrays*, IEEE Press, Piscataway, NJ, 1995.

[4] Jamlos, M. A., M. F. Jamlos, and A. H. Ismail, "High performance novel UWB array antenna for brain tumor detection via scattering parameters in microwave imaging simulation system," in *2015 9th European Conference on Antennas and Propagation (EuCAP)*, Lisbon, Portugal, Apr. 2015.

[5] Angel, J. J. and T. A. J. Mary, "Design of vivaldi antenna for brain cancer detection," in *2014 International Conference on Electronics and Communication Systems (ICECS)*, Coimbatore, India, Feb. 2014.

[6] Alzabidi, M. A., M. A. Aldhaeebi, and I. Elshafiey, "Optimization of UWB Vivaldi antenna for tumor detection," in *2013 1st International Conference on Artificial Intelligence, Modelling and Simulation*, Kota Kinabalu, Malaysia, 2013.

[7] Wang, L., A. M. Al-Jumaily, and R. Simpkin, "Holographic microwave imaging array for brain stroke detection," *Journal of Signal and Information Processing*, Vol. 4, 96–101, 2013.

[8] Irishina, N. and A. Torrente, "Brain stroke detection by microwaves using prior information from clinical databases," *Abstract and Applied Analysis*, 2013.

[9] Zhang, H., A. O. El-Rayis, N. Haridas, N. H. Noordin, A. T. Erdogan, and T. Arslan, "A smart antenna array for brain cancer detection," in *2011 Loughborough Antennas & Propagation Conference*, Loughborough, UK, 2011.

[10] Mohammed, B. J., A. M. Abbosh, D. Ireland, and M. Bialkowski, "Compact wideband antenna for microwave imaging of brain," *Progress In Electromagnetics Research C*, Vol. 27, 27–39, 2012.

[11] Gupta, H., V. Maheshwari, and V. V. Thakery, "Brain tumor detection by microwave imaging using planner antenna," *International Journal of Bio-science and Bio-technology*, Vol. 8, No. 5, 201–210, 2016.

[12] Gupta, H. K., V. Maheshwari, and V. V. Thakery, "Miniaturized ultra wide band microstrip antenna with defect ground structure for brain tumor detection," *International Journal of Hybrid Information Technology*, Vol. 9, No. 11, 13–24, 2016.

[13] caliskan, R., S. S. Guletkin, D. Uzer, and O. Dundar, "A microstrip patch antenna design for breast cancer detection," *Procedia-Social and Behavioral Sciences*, Vol. 195, 2905–2911, 2015.

[14] Lalitha, K. and J. Manjula, "Non-invasive microwave head imaging to detect tumors and to estimate their size and location," *Physics in Medicine*, Vol. 13, 100047, Jun. 2022.