URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Use of Magnetometer for the estimation of location of hook-wire used in breast conserving surgery

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Abstract

Breast conserving surgery is a popular surgery to treat early stage breast cancer. In the mammogram image when the abnormal tissue is identified, computer guided stereotaxic needle biopsy followed by hook-wire localization takes place. This hook-wire having magnetic strength can be detected by using the magnetometer. The magnetometer consists of a hall sensor and a permanent magnet, and is able to detect the hook-wire and its margin in three dimensional directions. The magnetometer can be placed around the excised tissue containing hook-wire inside and it can provide the information about the magnetic strength. By the help of an algorithm, the information about location of the hook-wire and its margin can be obtained. Depending on that information surgeons can take a decision of a second surgery.

1. Introduction

Breast cancer detected at stage I and II, in many cases, gets treated by breast conserving surgery where the surgeon surgically operates and remove the cancer with a certain margin while leaving as much normal breast as possible. Some surrounding healthy tissue and lymph nodes are usually also removed in order to confirm all the cancer tissues are out. [1, 2] During this breast conserving surgery, a hook-wire is inserted in the cancer area with the help of image guidance technique and then based on visual approximation, a margin is drawn around the area of insertion of hook-wire. After the excision of the tissue, it is sent to X-ray to check the hook-wire location and also margin around the hook-wire. If the margin around the hook-wire is not appropriate, then a second surgery gets performed. This whole process requires X-ray facility to be present in the hospital and a radiology expert to do so. [3]

In this research, an alternate method is proposed where the magnetic field of the hook-wire inserted can be detected by the magnetometer. The information about the margin around the hook-wire can also be obtained by the magnetometer. Since magnetometer is a portable and easy to operate, it does not require any special arrangement and any expert to confirm the information required.
Although it does not provide any visual information about the cancer like the X-ray facility, it provides a quick information about the hook-wire location and margin around it.

2. Method

A magnetometer with a permanent magnet and hall sensor placed inside was used for estimation of location of the hook-wire in three-dimensional directions. [4] The hook-wire is having an asymmetry structure, so it is important to measure the magnetic field from different directions in order to confirm the exact location.
In following sections, key components such as structure of magnetometer, structure of hook-wire and algorithm based on which the information of the location of the hook-wire can be obtained, has been discussed in detail.

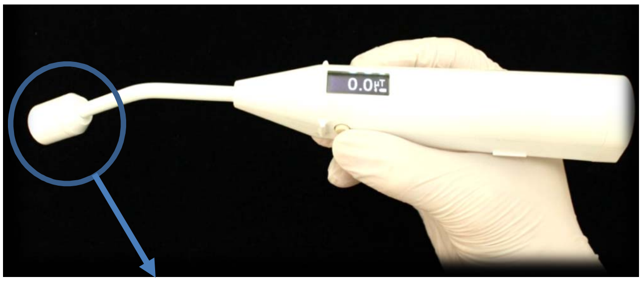
2.1 Structure of the Magnetometer

The magnetometer consists of a ring-shaped permanent magnet, small magnetic sensor and non-magnetic shaft. When hook-wire containing tissue comes close to magnetometer, the permanent magnet induces magnetization on the hook-wire and hall sensor which is placed in the magnetometer identifies the presence of the hook-wire by detecting this magnetic field. [4-6]

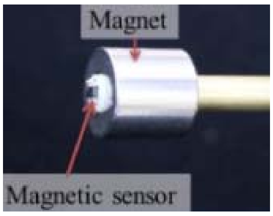
This variation of magnetic field is highly dependent on few parameters:

(1) Magnetic field created by the hook-wire
(2) Distance between the sensor placed on the magnetometer and the hook-wire

In different cases of hook-wire making angle inside the tissue, magnetic field detected varies and henceforth the location of the hook-wire can be estimated by the magnetometer
Figure 1. (a) shows the structure of the magnetometer and figure 1. (b) shows the top part of the magnetometer where the magnetic sensor and permanent magnet is placed. The magnetometer is easy to use and light-weight. Hence can be placed around the tissue. A display and a speaker giving clear indication about the stronger magnetic field makes it easy to use and understand.



(a)



(b)

Figure 1. (a) Basic structure of the magnetometer and (b) the placement of the magnetic sensor and permanent magnet at the top of the magnetomemeter

This magnetic sensor is placed in such a way that it does not detect the magnetic field generated by the permanent magnet but only from the magnetic object placed in the front.
Thus the magnetic field generated by the hook-wire can be detected by the sensor.

2.2 Structure of the Hook-wire and Experimental set-up

The second important component is the hook-wire which is commercially available and used by surgeons normally for the breast conserving surgery. The hook-wire is consisting of stainless steel. Diameter of the hook-wire is 0.54 mm and the total length is 300 mm. The hook portion length is 15mm and distal 25 mm is used by surgeon for landmark.
Depending on the length inserted inside the tissue, it can be divided into two parts: bendable part and rigid part. These two parts have different diameter and as the name suggests, one can bend inside the breast tissue as the tissue is soft and another cannot be bend. Figure 2 shows image of the hook-wire and the rigid part more elaborately. The length of the rigid part is 25 mm.

The hook present at the top which is rigid in nature, has different magnetism magnitude than rest of the part because of the structure. As the distance between the rigid part and magnetometer reduces, the magnetic field detected by the magnetometer also increases.

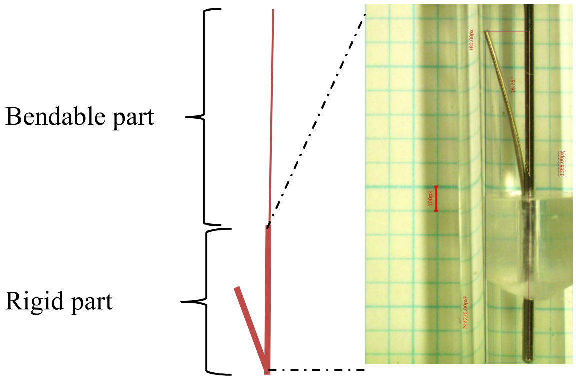


Figure 2. Structure of the hook-wire and the rigid part of the hook-wire

Since the rigid part does not bend, the bending is considered only by the upper part.
In the experimental set-up the hook-wire is placed inside the sample made up of acrylic which is a mimic of tissue. The magnetometer is rotated around the hook-wire and at various vertical levels the recording of the magnetic strength of the hook-wire is measured. During the recording of the data, the distance between the magnetometer and phantom has kept 200 mm.
Figure 3 shows a schematic diagram that how the hook-wire is placed inside the sample. In z axis, from z-10mm to z-50mm, every 10mm the measurement is done. In x axis, every 30°, rotational steps, Ω is measured for 360°. That gives 60 sampling points after every measurement of one data set.
This measurement is done for each sample containing the hook-wire. Sample varies in structure, since the bending is considered to be different in each case. The sample varies with different angles made by bendable part of the hook-wire and the placement of the hook-part in those sample.

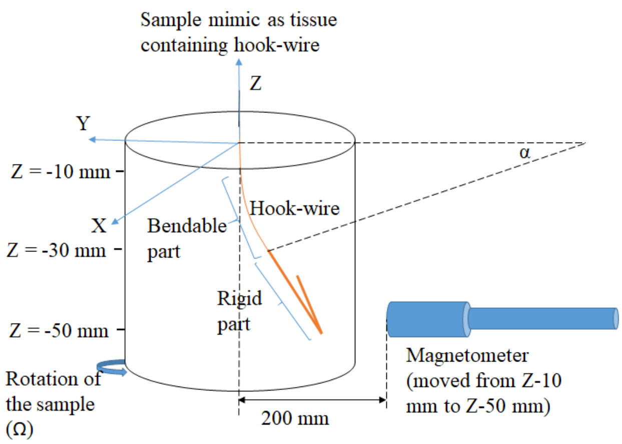


Figure 3. Measurement set up

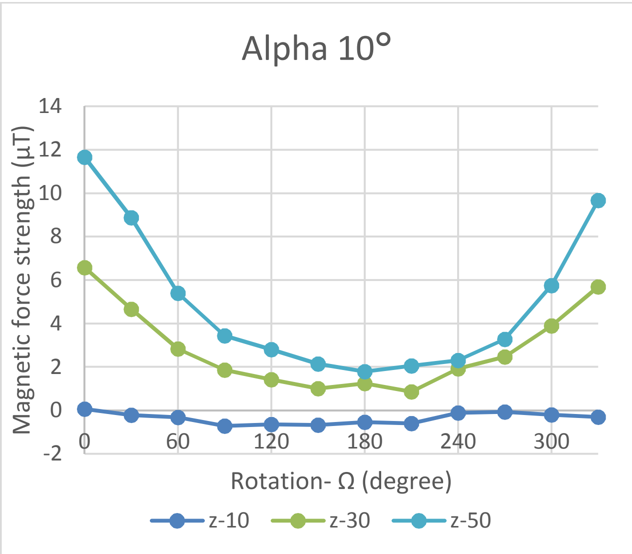
Magnetometer would record the magnetic strength of the magnetometer. That information would be used to estimate the location of the hook-wire and margin around it. For this reason, an algorithm is used in order to get the information required.

2.3 Algorithm to locate the margin

The experiments are done in order to get an extensive set of data. The hook-wire was placed inside the sample of acrylic which is a mimic of the excised tissue. Different conditions are applied in the sample and the data are recorded.
With the help of interpolation technique, in multivariate interpolation on a three dimensional regular grid, a point gets approximates. By using the information of the data on the lattice points, it is approximated on an intermediate point within local axial rectangular prism linearly. [7]
Since the data set is extensive and henceforth an optimization technique is applied, so that the function containing the information about the three-dimensional axis can be reduced. [8]

3. Results

The experimental result for the hook-wire magnetic strength shows variation in the amplitude in 360°, due to the rigid part's asymmetry structure.
Different cases are analyzed with different bending situation and it was found that the magnetic strength varies with a large margin in amplitude due to the bending of the hook-wire.
Figure 4 is an example of one case where the bendable part was making an angle 10° (α=10°) and magnetometer is moved in three vertical location and data is measured for every 30° data covering whole 360° (data for each rotational steps, Ω).



(b)

Figure 4. Magnetic strength value for three z level data

In above mentioned case, clearly with each z level change approximately 6µT magnetic strength changes in the starting point.
Also when the magnetometer moves towards the rigid part of the hook-wire, since the distance between them reduces to 6.57mm, the detected magnetic strength increased 6µT.
In 180°, the y axis distance between the magnetometer and hook-wire tip increases and approximately 7 µT magnetic strength changes.
Hence, we can identify the rigid part and can calculate the tip of the hook-wire and margin around the hook-wire. These results are used in order to estimate the hook-wire location exactly and also the margin around the hook-wire.

4. Conclusion

From the data obtained, it can be said that magnetometer can estimate the location of the hook-wire and henceforth the margin around it can be calculated. Thus this can be an alternative method than using X-ray. Especially for the hospital not having X-ray this method can provide a quick information (within 5-10 minutes), about the hook-wire location and the margin around.
Surgeons can take a decision about the second surgery (if required), within first surgery's 5-10 minutes and can perform in the same time.
Although this method does not provide any visual information about the cancer tissue or normal one, like X-ray; but this method can be done quickly for assisting the surgeon about the hook-wire location and margin around it.
The magnetometer is portable, light weight and does not need any expert to operate it. This makes it a very suitable option for the surgeon to use for getting quick information.

5. Acknowledgements

This work is supported by the Development of Medical Devices and Systems for Advanced Medical Services of the Japan Agency for Medical Research and Development (AMED).

6. References

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