

A Portable Electronic Platform for Breast Cancer Diagnosis: Developing a New Class of Biomedical Systems

It was quite late in the night when I got a very tense call from my friend. It had been almost five years since I spoke to him. I was in the lab immersed in a very exciting paper that had been published recently, and the call took me by surprise. On the other end of the phone, I could hear my friend almost breaking down into tears. His mother had been diagnosed with Stage II breast cancer and it came as a shock to his entire family. He informed me that he was holding the test results in his hands and it all seemed Greek and Latin to him. The doctor had just informed them that the results were positive for breast cancer. Before I could continue the conversation, his mother snatched the phone from him.

“How are you son?”, she asked. “I am good Aunty. Please don’t get tensed. With medication and correct treatment, the disease can be managed” I said to her. “No son, I am not tensed. I am in fact curious and I have a lot of questions for you” she said with an uncharacteristic calmness that I least expected. I could guess that she was having the results in her hand. She asked me, “Son, I understand with my general knowledge that cancer occurs when the cells in our body grow without control and stop obeying the usual control signals that make deviant cells kill themselves. But, what does this stage mean? I see a lot of abbreviations here such as HER2 status, ER, PR status, FNAC etc. What does all this mean son? And before all that, the last I remember you were working for a company that makes embedded systems. How come my son is clarifying doubts about breast cancer with you?”. There were a lot of questions that were shot at me at one go. I decided to calmly answer each of her queries with the hope that at the least this conversation would make her feel lighter.

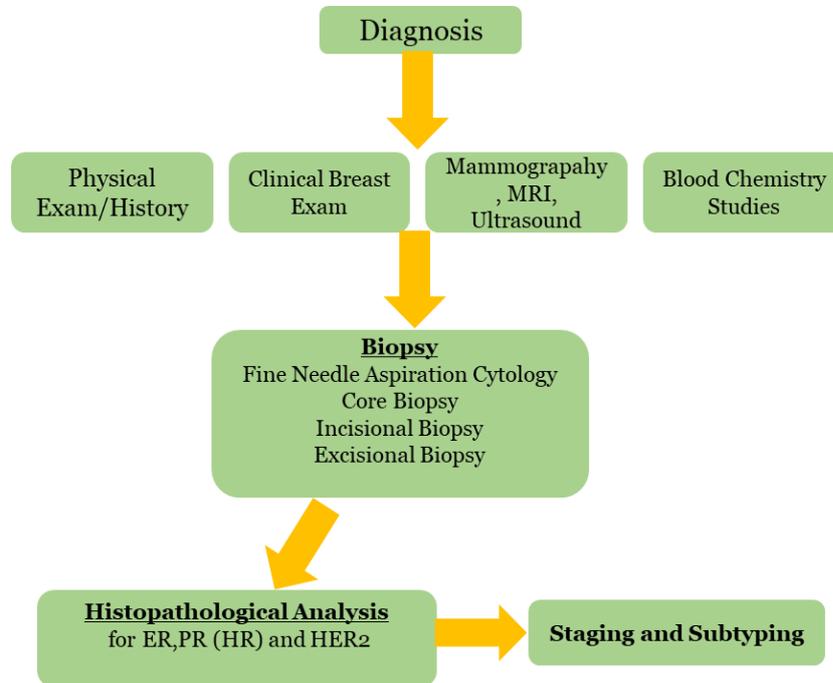
I told her that breast cancer is one of the most widespread forms of cancer affecting almost 1 in 22 women across the world. Each cancer, when diagnosed, is usually categorized into different stages depending on several parameters of the extent of the disease. For breast cancer and for many other cancer types these parameters are the size of the tumour (denoted by “T”), whether the cancer has spread to other sites in the body (a process called “Metastasis”, denoted by “M”) and the number of lymph nodes which have cancerous cells present (denoted by N). Lymph nodes are nodules of the lymphatic system which is another circulatory system like the blood. Cancer cells often spread to other sites through the lymph nodes. Depending on the values of these parameters the cancer is categorized into different stages. This process is called

“TNM staging”. At this point, she interrupted me with a sense of excitement, “Yes, yes I see it here in the report as well. They have written T1N2M0”. I replied to her, “Aunty, what that means is that the tumour in your body is less than 5cm in size, it has spread to 2 lymphatic nodes and that it has not spread to any distant organs, which is a good sign”. I could hear her heave a sigh of relief hearing this. “Ok, continue son, you are making me empowered. Anyone, suffering from any disease, must understand fully what their disease is all about. You are helping me with that”.

I continued to tell her that breast cancer is usually categorized into five stages, namely Stage 0 to Stage IV. Stage 0 is the pre-cancerous stage, Stages I and II are the early-stage cancer, Stage III is the locally advanced stage, where the cancer has spread to very nearby parts of the body and Stage IV is the metastatic stage which, as I mentioned earlier, denotes that the cancer has spread to distant organs of the body and formed tumours there. Very closely associated with this staging is a term called the “five-year survival rate”. This figure gives the percentage of people who have survived for five years after the diagnosis. In breast cancer, for Stage 0, the survival rate is almost 100% and the figure is 80-90% for Stages I and II. It goes down to as low as 20% for Stage IV. As soon as I finished telling this, she jokingly told, “So that means I have a fair chance of surviving at least the next five years!”. I told her, “Yes aunty, that is correct and even more, given that you have been diagnosed early on”. “Then what is this FNAC, ER, PR, HER2 etc. son?”, she asked.

I told her that any person who visits the hospital feeling a lump in their breast is first sent for a clinical breast exam where the doctor tries to touch and feel the lump that you reported and understand what it is. Following this, you will be sent for mammography and ultrasound scanning which is the screening method for detecting if there are any malignancies. Once the reports of these tests suspect something, you go to the next step called biopsy. Here again, they first start off with a very fine needle that will extract only a few cells from the breast. This is called Fine Needle Aspiration Cytology (FNAC). But the number of tests they can perform with this is limited. If the doctors want more tissue to carry out further tests or if they feel the disease is more advanced, they go for higher biopsies such as core, incisional, and excisional biopsy which takes out larger pieces of tissue from the breast. In breast cancer cells, certain molecules are present in higher concentrations than normal cells. Some of these molecules are estrogen receptor, progesterone receptor and human epidermal growth factor receptor 2 denoted as ER, PR, and HER2 in your report. The disease is treated in a different way depending on the concentrations of each of these molecules and accordingly, there are several

subtypes of breast cancer. She nodded in approval hearing this and I could feel a sense of confidence in her that came from beginning to understand the disease in her body.



Overview of the diagnostic and staging methodology followed for breast cancer

Then she asked, “So son, then what are you doing in this field, that too as a trained engineer?” I told her that after working for four years, I got an opportunity to do Ph.D. at the Indian Institute of Science in the department of BioSystems Science and Engineering. Here I am working on an interdisciplinary project with Prof. Hardik J. Pandya from Electronic Systems Engineering and Prof. Annapoorni Rangarajan from Molecular Reproduction, Development and Genetics department. I told her that the methods I had detailed here are currently affected by several shortcomings such as false-negative results (the tissue section that we take out may not have an increased concentration of the molecules which might be present in a tissue a little further away from the one that was examined), delay in getting the results (as it takes minimum a week’s time to get the receptor status), and the difficulty in identifying a type of cancer called triple-negative breast cancer (where all the molecules show normal concentration and yet cancer will be aggressive). To address these, we have developed a portable tool that is integrated with microsensors, electronic modules, and display systems that can measure the changing physical properties of the biopsy tissue such as its electrical, thermal and mechanical

properties. It is known that these physical properties are different for cancer tissues as compared to normal, but there has been no detailed study performed to leverage these properties and develop a system that can be used in the hospitals to aid in the diagnosis of cancer. Electrical resistivity, thermal conductivity and the mechanical stiffness of cancer tissues are different from normal tissues and we at IISc are developing a portable tool that can measure these properties in an hour's time to get an understanding as to whether the biopsy tissue from the patient is cancerous or not.

“That is very interesting son and would help a lot of people, especially in a country like India, where not all labs are equipped with all the expensive chemicals required for the conventional tests”, she said. “Yes aunty, we hope what we are trying to do will one day be placed in hospitals across the country helping labs to better diagnose the disease”. “That is indeed a great vision son. You have my blessings and best wishes for this noble endeavour”, she said. After speaking for a bit more time, she ended the conversation more confident and with a new-found sense of hope. I felt contented that I could help someone feel relieved.