MAPPING THE HUMAN BODY: THE IMPORTANCE OF CROSS-DISCIPLINARY THINKING

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Abstract

The history of scientific thought is marked by spikes of revolutionary thinking, followed by periods of evolutionary consolidation. Both are essential components in the continued development of our understanding. Generally, the revolutionary spikes are instigated by a few (or often one) maverick thinkers who are willing to reassess the conventional wisdom and set out in a new direction. These revolutionary spikes are temporally well spaced, but even during the evolutionary periods, there is a requirement for continual reassessment of the relevancy of other disciplines to one's own. This paper examines one such example of the combination of disciplines (radiography and geography) that might otherwise be considered disparate and goes on to make some general observations about the importance of such activities, some recommendations for scientists looking to investigate their applicability to their field of expertise.

Mapping has been part of the discipline of epidemiology for some time now. The genesis of the modern discipline of Geographic Information Systems (GIS) can be traced back to the work done in London in 1854 by John Snow, where the location of cholera cases was marked on a map with pins and the proximity to various drinking water wells calculated. This led to the identification of one of the wells as being contaminated and the removal of the handle of that pump so that the epidemic was contained. More recently, the spread of diseases has been modelled using sophisticated mathematical algorithms and visualised with advanced computational and graphical techniques. Both of these examples however, work on a scale beyond that of the single human. Applications of the numerical techniques used by geographers to the human body have been limited.

Geographic information systems

Rhind (2005)[1] defines Geographic information systems as follows:

> *"Geographic information systems (GIS) are a means of storing, integrating, analysing and presenting geographic data. A typical GIS consists of a combination of computers, databases and software capable of processing and presenting different thematic data with reference to a single geographic framework. Each theme is a layer of data that is linked geographically to other data layers of different themes. A GIS can be used to project combinations of geographical interrelationships of the various data layers onto a single map. Conversely, individual themes can be separated from the overall matrix and considered individually. GIS can provide insights into complex relationships not easily studied or observed by other means."*

The key point here is that the data are geographic, that is they have a location in relation to some coordinate system and can be compared with other data located in the same coordinate system. The term geographic can sometimes be confusing in that it implies that the coordinate system must be terrestrial (or, occasionally, ex-terrestrial, such as the GIS showing the surface of the moon and data about the various missions there). This is not the case. The data merely need to have some coordinate system in common. This system can be a common system, for example latitude and longitude or a local coordinate system like Universal Transverse Mercator. But it may also be an arbitrary system for locating data that only makes sense in the context of that data. A generalised schematic representation of the body is an example of this and as long as the same schematic representation of the body is used for all layers of data, relationships between the data can be studied, analysed and presented.

Lymphoscintigraphy

Lymphoscintigraphy is a technique whereby the path from the site of the primary lesion of a melanoma through the lymphatic system to the draining node fields can be recorded. This is achieved by injection of the radiopharmaceutical Technetium-99m-antimony sulphide colloid (^{99m}Tc-Sb_2S_3) around the biopsy excision site or primary lesion. Images of the tracer moving through the lymphatic system are captured using a digital gamma camera and are computer enhanced to ensure that even the faintest channels are detected.

Once the channels have been defined, they are marked on the skin of the patient by the physician for use by the surgeon. In addition to the channels, interval nodes (nodes along the channel but not in the lymph node fields) and sentinel nodes (the nodes to which the lesion directly drains) are also detected and marked.

This technique allows draining node fields to be accurately sampled for the presence of metastases with the minimum of surgery. It also ensures that all relevant material is removed, even if the paths taken through the system or the draining node fields themselves are different from those predicted by traditional methods.

Traditional medical concepts of lymph node drainage paths date back to 1843 when Sappey injected cadavers with mercury to trace the paths taken through the lymphatic system from various points on the body (Sappey (1843) cited in Uren et al. (1993)[2]). Lymphoscintigraphy has shown these concepts to be incorrect in a large proportion of patients.

Mapping the primary lesions and their draining node fields allows the researcher to quantify the divergence of paths actually taken from those predicted by Sappy and analysis of the factors influencing such divergence. Plots of all primary lesions draining to a particular node field can be used to establish the general pattern of distribution. With the addition of colour, it can be shown that the rather arbitrary lines traditionally used to delineate watershed boundaries in the lymphatic system are much less precise than was formerly thought.

Mapping the human body – an example of cross-disciplinary science

The results of this technique, which was performed on over 1000 patients, were recorded in a spreadsheet and then transferred on to schematic maps of the body using a GIS (ArcViewR). The images produced were used to examine some of the commonly held perceptions about the node fields to which lesions on various parts of the body drain. We have found using lymphoscintigraphy that the traditional concepts of lymphatic drainage in the skin proved to be incorrect in a large proportion of the patients. Displaying the information using the images produced by the GIS was a simple and effective way of illustrating this.

As a by-product of this research, a software application was developed which allows the physician performing the lymphoscintigraphy to enter the data for a particular patient and produce a formatted schematic for subsequent use by the surgeon. The schematic displays the primary lesion site and the locations and depth of sentinel nodes in each node field. This schematic diagram can be kept as a permanent record of the lymphatic drainage pattern for each patient.

Day-to-day application – schematic visualisation

An application was developed which allows the physician carrying out the lymphoscintigraphy to record the details of the patient and the results of the investigation. The location of the primary lesion is recorded as a map number and x and y coordinates on that map. The draining node fields are recorded as codes showing the depth and number of sentinel nodes. For example 1.5la2 indicates that the left axilla field contains two sentinel nodes at a depth of 1.5cm. The name and sex of the patient, as well as the number of draining channels and the maximum separation between the channels are also recorded. There is provision for noting details of surgery performed immediately or as follow-up.

The primary storage of the data is currently in an Excel spreadsheet. This communicates with the GIS via DDE (in Windows) or Appletalk (on the final target system) and passes a script a list of the data for display in a report. The script processes the data and prints out a report based on it. This report can be sent to the surgeon and is also stored on the patient's file.

Research – challenging Sappey's lines

Over 1000 patients have undergone lymphoscintigraphy in this study. In each case, the draining node fields and the number and location of the sentinel nodes and any interval nodes were recorded in an Excel spreadsheet. The challenge inherent in using a GIS to map the data was that the locations were descriptive. Only a small sketch of the location had been recorded and the images produced by the lymphoscintigraphy did not have any common reference points marked to allow normalisation and automatic geocoding of locations.

Six schematic diagrams representing the surface of the body were drawn and a grid marked on them. Each case was manually reviewed and a map number, X and Y coordinate recorded for each primary lesion site. These coordinates were then randomised within the level of precision of the grid used to avoid clustering at grid points.

The consequence of having both the site of the primary lesion and the location(s) of the sentinel nodes was that a picture of the lymphatic drainage system was able to be produced with points at the locations of the lesion colour-coded based on their draining node fields. It was evident from the initial data that the sharp watershed lines predicted by Sappey were, in fact, merely fuzzy approximations and that patients would be much better served by advanced imaging techniques prior to surgery than by guesses based on Sappey's predictions.

Crossing disciplinary boundaries

While this is an apparently simple and perhaps unsophisticated example of inter-disciplinary science, it serves to illustrate some important principles in the identification of opportunities for collaboration and cross-pollination. The primary principle is to be able to step back from the minutiae and look about for others pursuing similar goals. In this case, there were common words used in both fields. Geographic words such as "drainage", "watershed" and "channel", when used in a medical context, are an excellent indication that there is potential for some intersection between the disciplines. Similarly, both fields have a heavy emphasis on "imaging" and while they often use different techniques for collection and formats for storage of the data (medical imaging being heavily based on proprietary formats and geographic imaging being largely standards-based), these are merely technological differences rather than conceptual.

Moving outside an established field of expertise and engaging with specialists from disparate fields is often seen as potentially uneconomical in terms of the limited amount of time available to researchers. It is important however, for at least some of a scientist's time to be focused on expanding the boundaries of a speciality in a non-linear fashion. Attending seminars in fields that appear to be completely unrelated, perhaps as a part of a university's post-graduate seminar program, is one technique, as is an activity as simple as entering some of the key words from one's own field into a web-based search engine to see what other fields may also use similar terminology.

Once a piece of cross-disciplinary collaboration is underway, it is important to publicise the work in fora frequented by practitioners of both (or all) of the disciplines involved. Often this will mean presenting papers at disparate conferences, or publishing in multiple journals. The emphasis may change for each audience, but the essential value of the cross-disciplinary approach should encourage additional work between the fields.

Finally, it is incumbent on all scientists to remain open to the possibility of cross-disciplinary opportunities. No field of science is an island and while each seems to become more specialised and more insular, history has shown that the revolutionary breakthroughs made have very often come with the introduction of ideas from outside the field.

Acknowledgements

The author gratefully acknowledges the work of Dr Roger Uren and the cross-disciplinary vision of Professor Alan Coates. □

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