The use of mapping in public health and planning health services

Andrena Gordon and John Womersley

Summary

The availability of relatively inexpensive, user-friendly geographical information systems, with a steadily extending range of analytic and other facilities, provides a powerful tool for the analysis and display of the increasing number of health-related data sets, and for their greater accessibility. Relationships between several sets of variables can become immediately apparent from a map in a way that is much more difficult to comprehend from a table or description. It is also easy to define ad hoc areas, such as the area adjacent to a possible toxic point source or to a main road, in terms of unit postcodes and Census output areas, to determine standardized rates for mortality and hospital admissions. Apart from the geographical information system itself, the basic requirements are access to relevant data sets including Census data, and to the central postcode directory, which provides grid references for unit postcodes and permits matching of postcoded health events to Census output areas.

Keywords: mapping

Introduction

Maps have been used as a public health tool for over 150 years. In Glasgow, Robert Cowan produced a map which showed that fever was most prevalent in the overcrowded districts, and attributed the worsening mortality to 'excessive immigration without any corresponding increase in housing', and to the 'steady decline in the proportion of the wealthy middle class'. Robert Perry showed six-fold differences between parts of Glasgow in the proportions of the population attended by the district surgeons for fever, and demonstrated the extent of the 1843 typhus epidemic on a map on which affected households were individually identified. The map was printed and coloured by the inmates of Glasgow lunatic asylum 'in order to aid the design of Dr Hutchison in exercising the mental and bodily facilities of the inmates'.

In the 1960s and 1970s, Melvyn Howe used maps to demonstrate the considerable variation between wards in all cause mortality and in mortality from specified causes. He was able to show, for example, two- or three-fold variations between adjacent wards in mortality from ischaemic heart disease; as these wards shared the same water supply the water was unlikely to be an important causative factor.

More recently, geographical information systems (GISs) have been developed for health service use, and a wide range of possible functions was described by Nicol in 1991. Examples of these applications have been published. The purpose of this paper is to demonstrate how maps have been used in a health authority and associated Trusts, and to encourage others working in the health information field to use the relatively inexpensive and easy-to-use facilities now available to develop GISs of their own.

Methods

There are a wide range of GISs currently available for use. The biggest dilemma is in deciding which system to choose. Many factors have to be considered when assessing the suitability of a system, including user requirements (costs, a networked or single-user system, compatibility with other software, technical support). Costs quickly escalate if the basic system requires a number of additional add-on modules to meet the required specification.

We purchased a single-user MapInfo version 3.0 for Windows because this desk-top mapping system offered a wide variety of facilities at very modest cost (approx. £1000) compared with other systems. Several other users in the health service, local authorities and research institutes were also using, or intending to use, the same system. Technical support (by telephone) was purchased for an additional sum (about £300) and this was very satisfactory, although with the excellent manuals and tutorials (provided with software) it was rarely used. The compact and user-friendly nature of this system is ideal for use by those inexperienced in the field of GISs.

Digitized boundary data at postcode unit (e.g. G12 9LY) and postcode sector (e.g. G12.9) data for our health board area had already been obtained from the General Register Office (Scotland), although in an older GIS format. A MapInfo Translator package allowed the conversion of these boundary data for use in MapInfo, although these digitized postcode boundaries are now

Health Information Unit, Greater Glasgow Health Board, 225 Bath Street, Glasgow G2 4JT.

Andrena Gordon, Medical Geographer

John Womersley, Consultant in Public Health Medicine

Address correspondence to Andrena Gordon.

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available in a MapInfo format. New boundaries can be created by using the mapping system tools to aggregate postcode areas. This has allowed us to create catchment areas (e.g. for hospitals, clinics and schools), health authority areas and local authority areas from the original digitized postcode boundary data.

Data are stored on the mapping system as a database; the results of analyses or enquiries may then be presented on a map or in a tabular or graphical form. Multiple enquiries can be performed by building up maps as a series of data layers. Basic statistical queries can also be performed on the data with the software supplied; more complex statistical techniques are performed using statistical packages such as SPSS for Windows, and the results input to the mapping system. As the system is compatible with most popular databases and spreadsheets, inputting and outputting data is straightforward.

The databases most frequently used in mapping are:

1. Data available for Census output areas, enumeration districts, postcode sectors and wards: demographic and socio-economic variables from the Census; indicators of deprivation (e.g. Carstairs, Townsend, Jarman).
2. Data available at unit postcode level: locational information for a whole variety of health service facilities and also for nursing and residential homes, schools and social work premises; computer files from the Register General for Scotland giving details of all deaths, births and stillbirths; computer files of all hospital discharges and cancer registrations; information relating to general practices, including unit postcode of residence of all patients, prescribing data and a number of maternal or child health variables; those infectious diseases which are reliably notified (e.g. tuberculosis).

Place of residence or the location of a facility is identified from the unit postcode. To convert the unit postcode to a point location on a map the central postcode directory is required; this includes a six-figure coordinate for each unit postcode.

Uses

Describing the population and illustrating service provision

At its simplest level, the mapping facility is used to portray variations in the demographic, socio-economic and health characteristics of a population, and to display physical features such as health and social work facilities, roads and other transport links. Presenting the data as a map, superimposing layer on layer, can make relationships more apparent. In many instances, simply presenting data in a geographical context can suggest possibilities for further discussions or analysis. Table 1 gives examples of the types of questions posed.

Figure 1 shows the three postcode sectors (two of which comprise a post-war housing area, the other an older residential area) in an area called Drumchapel and another seven in the affluent suburb of Bearsden and Milngavie. The shading of each postcode sector is a measure of its degree of deprivation according to a classification of Glasgow postcodes into eight neighbourhood types; this classification was derived by principal component and subsequent cluster analysis of a wide range of 30 Census variables. The bars within each postcode sector give relative indicators of three socio-economic variables (unemployment, car ownership and owner-occupancy) and of the standardized mortality ratio (SMR) for males aged 0–64 years. High SMRs are observed in the most deprived areas, whereas owner-occupancy and car ownership are low and unemployment is high. This simple but effective presentation highlights the socio-economic divide between two adjacent geographical areas.

Defining catchments and practice populations

Maps provide by far the most effective means for demonstrating the location of residence of people using a particular facility such as a general practice, a clinic or a hospital. A particular service within a clinic or hospital, or people with a particular condition or type of presentation (e.g. elective or emergency cases) may also be selected. Alternatively, the relationship between two services or facilities may be investigated – for example, plotting the general practices which do or do not refer cases to a particular hospital together with an indicator of the proportion of all referrals from each practice which are made to the specified hospital.

Table 2 illustrates some of the ways in which MapInfo has been used to identify catchment areas and populations.

Figure 2 shows the distribution of the postcode of residence of patients registered with a particular general practice. As more than one person can share the same postcode, the
Variables

- % Males Unemployed
- % H/Holds with No Car
- % Owner Occupied H/Holds
- Male SMR

1991 Neighbourhood Types

- 1: Most Affluent
- 2: Affluent
- 3: Mixed Tenure; Single people
- 4: Inter-war Local Authority
- 5: Post-war Local Authority; Skilled labour
- 6: Mixed Tenure; Single people, immigrants
- 7: Post-war Local Authority; Unskilled labour
- 8: Inner City

Figure 1 Variations in socio-economic and health characteristics between adjacent localities.
locations are shown as a series of graduated circles, with the largest circles indicating the location of between 25 and 60 patients and the smallest circles between 1 and 5 patients.

Relating health and health service provision or uptake to deprivation

The quantitative relationship between measures of health status or health service utilization and deprivation is most clearly demonstrated as graphs or histograms and tabulations. However, sometimes it is helpful to identify the spatial distribution of these measures within and between areas, or even to determine exactly where patients come from, and for this a map is required. Maps are also the most suitable form of presentation for showing the relationship between deprivation and the availability of different kinds of facilities and/or the use made of these facilities. Examples are given in Table 3.

Understanding localities

Localities provide a population base which is small enough to have some degree of community identity, to establish effective joint working between different statutory authorities (and voluntary bodies) and to allow services to be effectively focused on population subgroups (e.g. ethnic minorities, single parents) which are of manageable size. To improve the health of localities a clear understanding is required of demographic and socio-economic characteristics, of health care needs and of the ways that different agencies (health, housing and social work) operate. The degree of concordance between general practice and locality populations is also of great importance. MapInfo has been used in this context as shown in Table 4.

The shaded area in Fig. 3 represents one of 19 ‘localities’ within the Greater Glasgow Health Board (GGHB) area. Only 68 per cent of people living within the locality are registered with general practices which are located within the locality. The remainder of the locality population is registered with a large number of practices outside the locality – most of which are nearby, but some are a considerable distance away. Although in some localities concordance between the general practice population and locality population is good, in most localities a considerable proportion of the population is registered with general practices some distance away and – conversely – a considerable number of people registered with practices located within the locality is resident outside the locality. This makes locality needs assessment, planning and purchasing difficult.

Table 2 Defining catchments and practice populations

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How closely does the actual catchment area of a hospital (defined by the postcode of residence of all patients discharged) match the theoretical catchment?</td>
<td>Patient referrals can be plotted using the patient’s postcode of residence in relation to the theoretical catchment area. The number and proportion of patients referred from within the catchment area can also readily be calculated.</td>
</tr>
<tr>
<td>To what extent do general practices situated within the normal catchment area of a hospital refer elsewhere?</td>
<td>Practice referral rates to particular hospitals can be mapped, sometimes illustrating striking variations in referral patterns; these differences may be associated with proximity to catchment area boundaries or may suggest that facilities in some hospitals may be perceived to be better than in others.</td>
</tr>
<tr>
<td>What will be the effect in terms of travelling distances of closure of a particular hospital?</td>
<td>Isochrones can be calculated around locations to determine the time spent in travelling. MapInfo offers an add-on module to provide this facility. Most GISs also provide this either as part of the base system or as an add-on module.</td>
</tr>
<tr>
<td>What is the distribution of the postcodes of residence of patients registered with a particular general practice?</td>
<td>It is possible to plot the postcode of residence of individual patients, to calculate the number of patients located within, say, a 1 and 2 mile radius from the practice, and to calculate the proportion of patients resident within any given area (Fig. 2).</td>
</tr>
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Table 3 Relating health and health service provision or uptake to deprivation

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
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<tbody>
<tr>
<td>How close is the association between standardized death rates or standardized hospital utilization rates and the deprivation category of postcodes, wards and other areas?</td>
<td>The standardized rates can be overlain on a map shaded according to deprivation category. The relationship between mortality or hospital utilization and deprivation category is immediately apparent.</td>
</tr>
<tr>
<td>How satisfactory is the distribution of pharmacies, both in total and in relation to the availability of special facilities (e.g. domiciliary oxygen, needle exchange)?</td>
<td>Mapping is an extremely effective way of identifying mismatches between services and facilities provided and population needs. This has been used, for example, to ensure an adequate distribution of pharmacies which participate in needle exchange in those areas where need is greatest.</td>
</tr>
<tr>
<td>Do women attending the continence resource centre come disproportionately from more affluent areas?</td>
<td>Mapping the postcode of residence of individual patients showed that this is clearly the case.</td>
</tr>
</tbody>
</table>
The shaded area represents the locality in which the practice is situated (with 24% of the patients).

51% of the patients are located within 1 mile of the practice.

82% of the patients are located within 2 miles of the practice.

Figure 2 Location of residence of patients registered with a general practice in relation to 1 and 2 mile catchments.
corridor either side of a main road, a catchment area or an area or areas around a toxic site. These areas may be defined on the basis of (unit) postcodes or distance measures (e.g. 1 km or 2 km radius). A computerized paper map image can be displayed as background information to assist in identifying the postcodes which make up such areas. Health-related data are obtained by matching the unit postcodes of the new derived area against files for particular health events (e.g. the unit postcodes of individuals who have been admitted to hospital or immunized). By matching the file of unit postcodes to the larger Census output areas or enumeration districts, the population of the area and its demographic and socio-economic characteristics may be determined, thus allowing rates – standardized where necessary – to be calculated.

**Migration**

The central postcode directory gives six-digit coordinates for each unit postcode. These can be used to identify accurately where people live and where health and other facilities are situated. Data containing information on patients registered with a general practice have been recorded on computer file by practitioner services [the Family Health Services Authorities (FHSAs)] for several years. Using the postcode of previous residence, and the postcode of current residence from this file, maps can be produced which show population movements both within the health authority and to and from places elsewhere.

**Other**

Examples of some other uses of the mapping systems are given in Table 5.

Figure 4 identifies postcode sector areas where the proportion of elderly people is above average (7 per cent), and shows how this distribution of elderly population relates to the siting of local private residential nursing homes (identified by black circles). In the darker shaded postcode sectors a nursing home is located in a postcode sector with an above-average elderly population; in the lighter shaded postcode areas there is an above-average elderly population, but no nursing home. In areas with a high proportion of old people but no nursing home provision it may be desirable to encourage some local nursing home provision, unless it is clear from the map that travelling by public transport (in more deprived areas) or by road (in more affluent areas) is likely to be relatively easy.

**Discussion**

Spatial analyses of health data have moved a considerable distance from the display of single variables on a map. This progress may be attributed to six main factors. First is the postcoding of the usual residence of people discharged from hospital, of births and deaths, and of certain other health events such as cancer registrations or attendance (or lack of attendance) for screening, immunization and family planning. Second is the fact that the smallest level of Census output (Census output areas) is defined as unit postcode aggregates. Third is the availability of the central postcode directory, which allows numerator (health events) data to be matched to denominator (Census) data for calculation of rates (standardized where necessary). Fourth, an increasingly wide range of health data has become available and the mechanisms for analysis of this and Census data have greatly improved. Fifth, digitized unit postcodes are available for purchase, and mechanisms are available for building these up to Census output areas, wards, localities and ad hoc areas. Finally, microcomputer-based GISs which have a wide range of analytic and other facilities and are easy to use have become available.

We have used the GIS extensively for the display of demographic and socio-economic variables (from the Census) and of health indicators (from a variety of data sets) on a postcode sector and ward basis, and occasionally for Census output areas and even unit postcodes. It is also possible to include the location of health service and other facilities, and to plot the unit postcodes of residence of people attending a general practice, hospital, family planning clinic or other facility to determine catchment populations. By plotting patients' residences, health service facilities or health indicators against a background of postcodes or wards which are shaded according to deprivation status, it is possible to explore relationships between these variables.
Practices which have 10 or more patients resident in the Shawlands/Pollokshields locality are depicted on the map. There are an additional 134 practices (some far removed from the area shown in the map) which have between 1 and 9 patients from the Shawlands/Pollokshields locality.

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Scale: 1cm = 0.84km

Figure 3 Patients resident in Shawlands–Pollokshields locality attending general practices outside their locality.
Several nursing homes are situated in areas (particularly semi-rural areas) which have relatively low populations of elderly people.

Figure 4 Elderly population (75 years and over) in relation to the provision of private registered nursing homes.
Table 5 Other enquiries

- What is the geographical distribution of people with a particular condition (e.g. congenital malformation, leukaemia, bladder cancer), and how does this relate to possible toxic sources?
  Buffer zones over specific distances can be calculated around possible toxic sites or as corridors (e.g. either side of main roads), with incidences of disease plotted in relation to these zones. Evidence of possible 'clustering' of disease can also be identified.

- Where are the highest concentrations of unimmunized children or of women who have not been screened for cervical and/or breast cancer?
  Mapping the postcode of residence of individual patients can help to answer questions such as: is accessibility to services a key problem in those areas identified as having poor uptake rates or screening rates? Would the location of a mobile screening service help to improve rates in these areas and, if so, which are the most suitable locations?

- Which practices are 'high preservers' of a particular drug, where are these located and how does their location relate to the proportion of elderly people on the practice list, deprivation and other factors?
  It is possible, for example, to standardize prescribing costs (overall or for a particular drug) to take account of differences in the proportions of elderly patients in general practices and to show these on a map (e.g. as circles of graduated size) against a background shaded according to deprivation category.

The analytic facilities of the new mapping systems, however, provide the greatest potential for development. For example, the previously complex and time-consuming process of defining ad hoc areas in terms of Census enumeration districts or output areas through aggregating geographical data, and of obtaining standardized rates (e.g. for mortality or hospital discharges) is now a relatively routine exercise. Migration patterns and trends can also be readily analysed and clearly illustrated. Also, the calculation of catchment areas, population densities and buffer zones using a variety of distance measures is easy, and complex queries can be performed across the datasets before mapping, as many of the examples above illustrate. Finally, routing functions can be used to calculate the shortest and quickest routes between locations on a road network, and travelling time isochrones can be calculated from any location.

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