General practice and the new science emerging from the theories of 'chaos' and complexity

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SUMMARY
This paper outlines the general practice world view and introduces the main features of the theories of 'chaos' and complexity. From this, analogies are drawn between general practice and the theories, which suggest a different way of understanding general practice and point to future developments in general practice research. A conceptual and practical link between qualitative and quantitative methods of research is suggested. Methods of combining data about social context with data about individuals and about biomedical factors are discussed. The paper emphasizes the importance of data collected over time and of considering the multiplicative interactions between variables. Finally, the paper suggests that to develop this type of research, general practice may need to reassess systems of categorizing and recording appropriate data.

Keywords: general practice; world view; chaos theory; complexity.

Introduction

MEDICAL science uses two main research approaches: the study of groups, including epidemiology and randomized controlled trials; and reductionism, studying the details of biology and pathology. General practice uses this medical knowledge but also has its own perspective. Analogies are drawn between this perspective and the theories of 'chaos' and complexity, which suggest alternative directions for future research.

The general practice perspective

The core activity of general practice is the consultation[1] where a patient's problem may be assessed in biomedical terms; their hopes, fears, and expectations explored; and the effect of their social situation discussed.[2] The doctor listens to the patient's account, forms a diagnosis of the problem as assessed so far, but may then use observation over time to refine the diagnosis.[3] This observation is important even where a biomedical diagnosis is made or excluded.[4]

Using biomedical evidence in general practice is not straightforward. For example, evidence from groups cannot predict what will happen to an individual patient,[5] and the use of interventions for prevention, developed to improve the health of the community and accepted as part of general practice,[2] may depend on the patient's and doctor's context.[1,6]

The theories of 'chaos' and complexity

The theories of 'chaos' and complexity have developed from diverse fields including experimental mathematics, evolutionary biology, and social sciences. The common theme is how systems, that are internally complex, undergo changes over time. A system may be a mathematical computer model, a weather system, or the complex social and biological entity of an individual, family, or neighbourhood. Traditional linear science describes scientific laws where, if we know the initial starting condition of a system and the linear laws governing its behaviour, we know what will happen to it over time following a change in the conditions affecting it. This is the basis for controlled experiments. However, the theories of 'chaos' and complexity suggest that much of the world is not linear and small changes can produce dramatic transformations of an entire system. This is particularly likely when the state of a system is a product, not just of the value of key variables but of non-additive interactions between them. An example is the 'butterfly effect' describing the 'chaotic' character of weather. A tiny difference in the initial conditions of a weather system, equivalent to the force of a butterfly's wing beat, may, over time, make the difference between the development of a hurricane or a calm.

A complex system at one level of analysis; for example, an individual, will affect and be affected by changes at other levels; for example, at the level of biochemistry or at the level of social structures. However, each measured change cannot fully account for the subsequent changes in the system. So the system cannot be understood by analysing the complex whole into its constituent parts. For example, individuals are more than the sum of the multitude of complex biochemical reactions taking place in their bodies,[7] and social phenomenon cannot be fully explained in terms of the individual actions of people.[8]

Formal mathematical ways of representing complex systems have been developed. A complex system, such as the health of an individual, could be described in terms of numerical values of a range of variables. A complete description would include all the variables that we know affect an individual's health and that we can measure. It could also include variables that are difficult to measure but are apparent, such as the effect of caring,[9] and variables that we do not realize are important. A working model may not need to be complete in terms of including all possible variables, as only a small number of variables are likely to control the outcomes for the system. A model of an individual's health has as many dimensions as there are variables, plus the additional dynamic variable of time. If there are n variables, there are n+1 dimensions. We can trace the location of the system, our individual, through time. The position of the system is defined by the n coordinates representing the values of the variables in our model. This changes with changes in one or more of the variables. The changes in position may not be simple and predictable but radical and different. If the world was random, any change in the system could produce any result. However, mathematical theory has identified that, within the space defined by our n+1 coordinates, there are subspaces where the system tends to settle. Systems change in ways that do not use of the whole of their potential space. In the example of the weather, the hurricane and the calm are two of the possible subspaces.

There is now considerable evidence that this mathematical idea corresponds to the way in which complex systems operate in the real world. A system may change gradually over time by

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small increments, test its boundaries, but remain stable. However, there may be points in time when quite small changes result in either one or the other of two radically different, relatively stable subsequent states, as with the butterfly and the weather. Another example is the classic 'crisis' of a life-threatening infectious disease, when either a patient overcomes the infection or the infection overwhelms the patient and the patient dies. Medical interventions try to tip the outcome in the direction of life instead of death: the two potential states available.

For a complex system, finding where the dramatic changes occur can be established by observation of the development of the system. This suggests that only once a dramatic change has occurred can the controlling variables be identified. As small changes in a system may produce very different outcomes, it could be argued that no prediction is possible, and so it cannot be established that any particular intervention can be used to alter a system in a desired way. However, both experimental mathematics and evolutionary biology point to the existence of recurring patterns in dynamic, complex systems and suggest that observation is needed to perceive patterns in the world but these can then be tested mathematically to check that they are recurring and to check how they come about. The theory suggests that systems obey rules, although they may be different from traditional linear rules, and, if the control variables and the non-linear effects are identified, it may be possible to understand how an intervention may enable some things to happen and others not.[10]

Analogies between 'chaos' and complexity and general practice

The assessment of an individual in general practice is a description of a complex system at a particular point in time. The focus is on the individual, but account is taken of interaction from other levels of analysis. Nested within the individual are physiology, biochemistry, and genetics, and individuals are nested within the social system. The social system forms the space of the possible for the individual. For example, in a social system where there is relative poverty and affluence, this delineates what is possible for the individual.[10] The individual forms the space of the possible for biomedical variables. For example, being cared for can affect the outcome of a biomedical intervention.[9] A biomedical diagnosis interacts with the individual and with the social context, and may determine the boundary of the possible at higher levels of analysis; for example, where an individual has diabetes.

General practice has learnt to recognize patterns of health and ill health and how they develop over time. An individual may remain relatively stable with only small changes occurring over time. This could be a state of chronic health or ill health and may represent most patients presenting in general practice. However, general practice also observes major changes, such as the development of cancer or an intervention changing the course of an illness. The intervention may be easily defined and measured, such as the use of penicillin in pneumonia. However, it may be so small as to be essentially immeasurable, such as a difference in tone of voice of the doctor in a consultation.[11] It is likely that the number of factors controlling the outcome is relatively limited. We may know most of them from clinical experience, although many may not have been quantified. General practice knows how to use interventions, whether it is penicillin or conversation, to try to direct the patient towards a desired outcome. The intervention may not always have the expected result. This may be because of inaccurate assessment, but also incomplete assessment, where an unrecognized variable affected the system.

Future research

The theories of 'chaos' and complexity warn against attempting to predict outcome in a linear way, and suggest that the world may be better understood through observation of changes over time. From this, it may be possible to identify what factors were important in bringing about a change in a system. This requires data collected over time that accurately represents the state of the system at each time point. Studies need to be clear about the level of system at their focus. Data from other levels can then be attributed to each particular case at the level of interest. For example, general practice research may focus on the individual, using quantitative measures from standardized questionnaires and categories based on qualitative analysis such as the meaning of illness.[12] Each individual may have biomedical variables and a measure of risk of illness from epidemiological data.[13] Social measures or categories can also be applied to the individual; for example, living in a context where unemployment is high or low. This can be a separate variable from whether the individual is in employment or not. The value of the variables would change to reflect changes over time.[10]

The analysis of a set of data collected over time will need to take into account interaction among variables, not just simple additive effects but multiplicative relationships. Two statistical techniques that can help are cluster analysis and loglinear analysis[14,15] repeated at the different time points for the data. Cluster analysis provides a descriptive account of the system, and when repeated over time it can reveal how the system changes. Loglinear analysis can tell us which variables or interaction of variables are important in bringing about the observed changes.

Using data about the social context, individuals themselves and their biomedical variables, may lead us to an understanding of what brings about changes in individuals as complex systems. However, the answers may not be general laws but answers for the particular time and place where the study takes place. This does not mean it has no interest for other places. Data on the social context allows an assessment of the applicability of the results to another place. If not applicable, a further study could be carried out using the lessons of the original study, including what the control variables are likely to be. In current health service research, answers are often only local and have to be produced speedily to still be relevant at the end of the study, as the social context changes.[16]

The theories suggest a way of using quantitative data to follow the development of a system. Qualitative research provides description and analysis prior to the construction of categories or measurements.[17] It can also describe the overall state of a system, thus acting as a check on any quantitative description, expressed as the values of many variables, that may otherwise be difficult to interpret.

An example

There is evidence that brief advice from a general practitioner to give up smoking has an effect on smoking rates,[18] although how and why is not so clear.[19] In the United Kingdom, doctors are encouraged to use the idea[20] that the likelihood of an individual changing a health-related behaviour is related to their stage in a process of change.[21] However, there are many factors that influence smoking patterns. Social structural factors include the law on advertising and the tax system. Social trends include the impact of an advertising campaign, the local culture, and education. Micro-social influences include smoking in the family and among peer groups. Individual factors include age, sex, social class, occupation, income, and performance at school.[22] All these factors may change over time, sometimes quite rapidly, and may vary between localities. Interaction between factors may have an effect far larger than any one factor. Traditional research has not managed to unravel the question of why some people smoke and others do not, or give up, and, given the complexity of the problem, it is perhaps not surprising. It has been suggested that qualitative research may help to increase our understanding.[22] The approach suggested here brings together qualitative and quantitative approaches.

To try to understand why some people smoke and others do not, or give up, individuals could be followed over a period of time. Data about each individual would be needed, including smoking habit, their stage in the process of change, and data on the variables mentioned above. The data may be numerical or categorical. Data on the social context would be attributed to each individual for each time point for the data. Appropriate biomedical variables could also be included. This would provide a retrospective description of each individual and how they change over time. Some individuals may change from being a smoker to a non-smoker, and the data may reveal the controlling variables or interaction of variables. This observation of the patterns of change could be repeated for each individual and may reveal a number of different patterns of change that would be lost if the individual data was aggregated.[23] However, there may be controlling variables common to a number of individuals. If each individual data set was entered in a n+1 dimensional contingency table, with n the number of variables measured over time, cluster analysis could be used to identify subgroups of individuals. Repeating the analysis for each time point for the data would reveal any changes in the groupings over time. Where a change was found, such as part of a group becoming non-smokers, log-linear analysis could be used to try and identify which variables, or more probably which interaction of variables, were the main control variables for the observed change.

Such a model would require data difficult to collect across localities; however, in a local area, the combining of individual and social data may be possible. The model could not be predictive, but may indicate the main variables affecting smoking habit, so indicating what interventions are worth trying. Any intervention could then be included as a variable in the model and its effect watched over time.

There is already a large amount of data available about smoking, from which it may be possible to develop a model using aggregated data. Such a model would be constructed at the level of analysis of society, rather than the individual. It may indicate changes that could alter smoking patterns in society but it would not tell us about what influences individuals. As general practice deals with individuals, we may want to develop our research through finding ways of tracking how individuals change over time, so the results of our research are at the same level of analysis as our clinical work, and so are more directly applicable.

Conclusion

There are analogies between the perspective of general practice and the theories of 'chaos' and complexity indicating that the methods of research for complex dynamic systems may be of use in advancing research in general practice. There are two current trends in general practice research that may appear contradictory: the promotion of evidence-based practice, with a high value given to numerical outcome research; and the increasing interest in qualitative research. The theories of chaos and complexity help us understand the link between qualitative research, where the results are categories of data and interpretation of meaning, and quantitative research, where outcome is measured.

The methods suggested in this paper use data that reflects what is happening in the world to identify points of major change and the control variables affecting the direction of change. General practice records, public health data, and social surveys provide data that could be used together. General practice records may be sufficiently accurate for providing categorical data for a longitudinal study despite their many shortcomings. The data may be mainly about clinical diagnoses and less about the individual and their social context; a balance that may need reviewing. If available data is used to get started on analysis, as suggested in this paper, it may become clear how refined our recording needs to be for research that aims to identify the main control variables for individual patients consulting.

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