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Computable knowledge is the enemy of disease

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INTRODUCTION

The memorable phrase 'knowledge is the enemy of disease' was coined by Sir J A Muir Gray, the founding director of the National Health Service (NHS) National Library for Health and Knowledge Service.[1] Of course, knowledge in healthcare is not only fundamental to clinical decisions, but is the very essence of education, public health and research.[2] Clinical decision support and data standards have long been central topics in health informatics, but the concept of 'computable', *executable* knowledge has gained traction more recently. This has been enthusiastically promoted since 2016 by a US-based network under the banner of 'Mobilising Computable Biomedical Knowledge' (MCBK).[3 4] At the suggestion of Professor Charles Friedman, Chair of Learning Health Sciences at the University of Michigan, a UK conference was held in October 2019 to bring together the national community of interest in computable biomedical knowledge. This supplement reports on that conference and signposts some of the future computable knowledge activities planned in the UK.

What is 'computable knowledge'?

Most health and care informatics activity concerns the capture, storage or communication of data about patients or clients. However, as Shortliffe argued in the first health informatics textbook,[5] patient data are only one part of the information needed to take decisions: we also need knowledge, such as the causes of disease, how it affects the body and the effectiveness of drugs or other therapies. This explains why Shortliffe defined information as 'organised data *and knowledge* used to inform decisions'.[5] Much clinical knowledge originates from aggregated patient data, but there are several differences between patient data and clinical knowledge, summarised in table 1.

In most disciplines, professionals need to acquire practical and cognitive skills or tacit knowledge through a period of training, and medicine is no exception. Fortunately, the content and format of medical training are very regulated so in healthcare, managing tacit knowledge is less of a challenge compared with other sectors. However, medical research has generated huge quantities of explicit knowledge (knowledge that can be written down and directly used by others) to which clinicians need access at the bedside. Explicit knowledge can change fast and varies widely in its quality and relevance to clinical practice, so managing it is a major challenge.[6] As a result, much research over the last six decades has focused on computerising clinical knowledge, often through decision support systems which automatically locate and select knowledge based on a patient's data, then synthesise it into advice relevant to that specific patient at that time.

Note that there is an important distinction between computer-*based* knowledge, which is held and shared in text format for humans to read (eg, a PDF patient leaflet or online HTML textbook), and computer-*executable* ('computable') knowledge, which is held in a format that can be reasoned with or applied by the computer to carry out a task.

Why does computable knowledge matter?

Despite many decades of research, computable knowledge is far behind computable patient data in terms of standards for provenance, coding and indexing. While the NHS does use computerised knowledge extensively (such as embedded calculators, risk algorithms, clinician prompts and checklists or drug interaction warnings) to support professionals and patient safety, unfortunately some of these are cottage industry products and have not been maintained or implemented correctly. As a result, at least eight serious algorithm-related incidents have occurred recently,[7] raising serious questions about the development, validation, use, maintenance and withdrawal of these computable knowledge systems. Further reasons why the NHS now needs to clarify the governance and

Table 1 Distinguishing knowledge from data

	Patient data	Clinical knowledge
Who it applies to	A single patient	Every patient
Where it comes from	A single patient	Research on many patients
Forms it can take	Numbers, codes, text, images, sounds…	Intuition (tacit knowledge), spoken word, written text, computer-based text, computer executable knowledge
Privacy issues	Significant, even if 'anonymised'	Not applicable
Intellectual property issues	Not at individual patient level	Significant
Scale of economic activity	Major global market in electronic patient records, etc.	Small, fragmented market in computable knowledge and decision support systems
Potential for clinical error	Exists, but implications usually modest	Large potential for safety issues resulting from incorrect or poorly implemented computable knowledge

lifecycle of computable knowledge and decision support is the increasing pressures on health systems and staff and the widening of the range of NHS providers, so that staff managing NHS patients in any organisation can all work to a common knowledge base and standards of care. Finally, there are a wide range of both public and private sector stakeholders who would use high-quality computable knowledge resources, if these existed—see table 2.

What are the challenges of computable knowledge?

Computable knowledge and clinical knowledge systems raise broad professional and technical challenges, including:

Professional challenges

Protection of intellectual property, freedom from bias, measuring and improving knowledge quality and currency, legal liability for suppliers and users of clinical knowledge bases and decision support systems; procurement or quality assurance of computerised knowledge; tracking the source of knowledge and how it has changed since the original version.

Table 2 Computable knowledge use cases

User group	Use cases for computable knowledge
Members of the public	Assessing health-related risks and how to manage them; what to do about acute symptoms
Patients (ie, people with a diagnosis)	Self-management: how to assess disease activity or progression; how to adjust therapy; when to seek clinical contact, and how urgently
Clinicians	To guide diagnosis, prognosis, investigation, treatment…
Public health workers	To assess and manage population risks, and contain epidemics
Software developers	To support the development of apps, medical devices, clinical information systems, chatbots and clinical robots
Medical publishers	To provide content for paper and online publications and decision support systems

Technical challenges

Encoding knowledge so that it can be safely reused in a variety of clinical systems; indexing computerised knowledge for accurate recall; locking the knowledge so that its integrity is protected; preserving the meaning of computerised knowledge when used in systems with different clinical coding systems; adjusting computerised knowledge to fit specific contexts (eg, primary vs secondary care guidelines); archiving of obsolete computerised knowledge to support later legal investigation.

Solving these challenges can help us address the two main concerns about computable knowledge:

1. *Sustainability*: helping knowledge authors and organisations to justify the significant extra work of authoring computable knowledge as well as human-readable text.
2. *Building user trust in a computable knowledge library* by:
   a. Quality assurance or validation of knowledge objects prior to library acceptance.
   b. Preserving the provenance, integrity and context of individual knowledge objects.
   c. Keeping knowledge objects up to date when a new study or guideline is published.
   d. Ensuring safe transfer of knowledge objects to systems using different clinical codes or semantics.
   e. For clinical decision support, ensuring that objects based on National Institute for Health and Care Excellence (NICE) guideline or systematic review overrule objects based on single study, clinical audit or opinion.
   f. Continuing quality improvement (eg, by routing user comments to the knowledge object author).
   g. Establishing lean governance structures and mechanisms.

Learning from the London conference

The technology advisor to the Secretary of State for Health and Social Care gave the opening speech, emphasising the crucial importance of high-quality information and technology in supporting optimal care delivery. Following opening talks by the co-chairs and an online presentation by Prof Friedman, the conference heard from several keynote speakers as summarised in this supplement.

NICE presented a view of how guideline development and publication need to change, describing exploratory work in progress towards computable clinical guidance.[8] Health Data Research UK reported on their contribution in the areas of open standards and computable phenomics[9] and NHS Scotland described their national decision support programme.[10] The conference also heard about practical approaches to achieving computable knowledge delivery,[1 11 12] a perspective from a medical publisher[13] and a panoramic overview of computer science issues in CBK.[14]

CONCLUSIONS

The main workshop conclusions were that MCBK is challenging but of great significance to future health systems, so should be supported and developed as a cross-sector activity by a working group consisting of both clinicians and informatics experts. This led to the formation of a joint working group by the British Computer Society (BCS, the Chartered Institute for IT), and the Faculty of Clinical Informatics (FCI), supported by an FCI secretariat. This group has met monthly since the workshop to develop a number of activities, both face-to-face and virtual. Face-to-face activities included a December 2019 workshop on trust and governance and plans for a 1-day national conference in early 2021, subject to sufficient relaxation of current pandemic lockdown rules. The BCS and FCI are working in partnership with Health Data Research UK to support the sharing of knowledge within their Better Care network and more widely across the health data community.[15] The work will help insights, learnings and tools required for the implementation of learning health systems to be shared. Through the partnership we will work to identify and spread actionable clinical knowledge in computable formats and facilitate access of this knowledge to developers of apps, GP templates and other decision support systems.

While progress has been slower than expected due to the COVID-19 pandemic, this crisis has helped to highlight what can happen *without* sufficiently mobilised knowledge that is shareable, executable and trustworthy.

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