Is IT a dangerous prescription?

Harold Thimbleby

A hospital has a poster on the wall next to the reception desk: "Notice to ALL patients. The [...] NHS Trust is currently in the process of introducing a new Patient Administration System. It may cause a delay in you being seen..."

What is it that computers and IT do to us that we have an overwhelming urge to introduce systems that make the world a worse place? No doubt if the hospital was worried about the poor performance of the systems they are introducing, they would be told to spend more money on IT!

Simply: if a proposed solution does not work well, something is wrong with the solution and the process that led to it, or the process that failed to get rid of it – though if it was the very first time this had happened we might be excused on the basis of "exploring the unknown".

But we are not exploring the unknown. The UK has had the largest civilian IT project in the world trying to sort out hospitals with IT solutions. That hospital with the patient delays wasn't the first to be computerised! And in the US, some of the evidence is not just that IT slows handling patients down but that it increases fatalities. In one paediatrics ward, a hospital IT system doubled fatalities (Han et al, 2005) and, for reasons spelled out in the paper, this could hardly be a surprise to any experienced developer – essentially an absence of effective user centred design. Indeed, it is surprising that so few places are evaluating the effectiveness of IT, and one certainly wonders about its overall effectiveness. Perhaps, overall the hospital might be saving more lives, but at a cost to paediatrics? Nobody knows.

In their report on a series of radiotherapy fatalities (IAEA, 2001), the investigators say (on page 80) – with my numbers for reference, and "[...]" for omissions:

> (1) It is questionable whether the information in the instructions was sufficiently clear [...] there was no warning on the computer screen when [the user did not follow the exact instructions].
>
> (2) A single error in the method of entering data [...] led to the delivery of wrong doses to patients and to severe, and in some cases fatal, consequences [...]
>
> (3) An efficient system for detecting and correcting errors ***therefore*** needs to be in place: this implies a QA programme with sufficient double and independent checks. A comprehensive QA programme needs to be in place in any radiotherapy facility. In addition to the staff involved in the implementation of the programme, all hospital managers and administrators need to be made aware of this and of the consequences of not having it, as part of their training. (My emphasis.)

How does the report fail to put (1) and (2) together when they are on the same page? Surely the instructions could be clearer and surely the IT system itself could notice an error? Why is all the QA responsibility left to the users of the IT system and not, at least in part, to its developers? We will have more to say about this incident later.

In August 2006 a cancer patient died from an overdose of a chemotherapy drug. Unusually, this incident was studied in a root cause analysis (ISMP Canada, 2007; Thimbleby, 2008) that, unusually, was made publicly available. The root cause analysis was thorough, but it indirectly exposed cultural problems behind the issues with which this article opened: complex IT systems are not understood by the healthcare profession, and without any pressure to do otherwise, manufacturers continue to provide "solutions" that, like badly developed drugs, have unwanted side-effects, causing delays or increased rates of fatality, or financial loss (through hospital liability as well as through national costs as patients taking longer to recover put financial burdens on their relatives and communities). In effect, healthcare is subsidising sick IT, as we shall now argue in more detail.

The patient was using a mobile infusion pump to continually deliver a chemotherapy drug for her treatment. This arrangement allowed her to walk around. She presented at a healthcare centre to have her supply of the drug replenished. Having identified the patient, a nurse went to the pharmacy to get a new bag of the drug; the nurse was given a bag and a printed chit – the paperwork is reproduced in figures 1 and 2. The nurse's job was next to reprogram the patient's infusion pump to deliver the correct rate of drug for the next four days. (Presumably it could have carried on at the previous rate.) The cancer centre's protocol is that two nurses should independently calculate the rate, then enter it into the device. In this case, both nurses made the same calculation error: they forgot to divide by 24 hours in a day, and thus got an hourly rate that was 24 times too high: 28.8 mL per hour when

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5-Fluorouracil 5,250 mg (at 4,000 mg/m2) Intravenous once continuous over 4 days
Cis_5FU_Part2-HN-CC - Cycle - 1, Day - 1
Substitutions Allowed
Administration Instructions:
Continuous infusion via ambulatory infusion pump
(Baseline regimen dose = 1000 mg/m2/day = 4000 mg/m2/4 days)

Figure 1 The paper chit accompanying the drug bag. The figure accurately reproduces the text, line breaks and font. Human factors experts and typographers may like to note the poor spacing, the use of / (which can be confused for 1), inconsistent use of commas in thousands, and other legibility problems (the m2/4 is particularly problematic); see also figure 2.

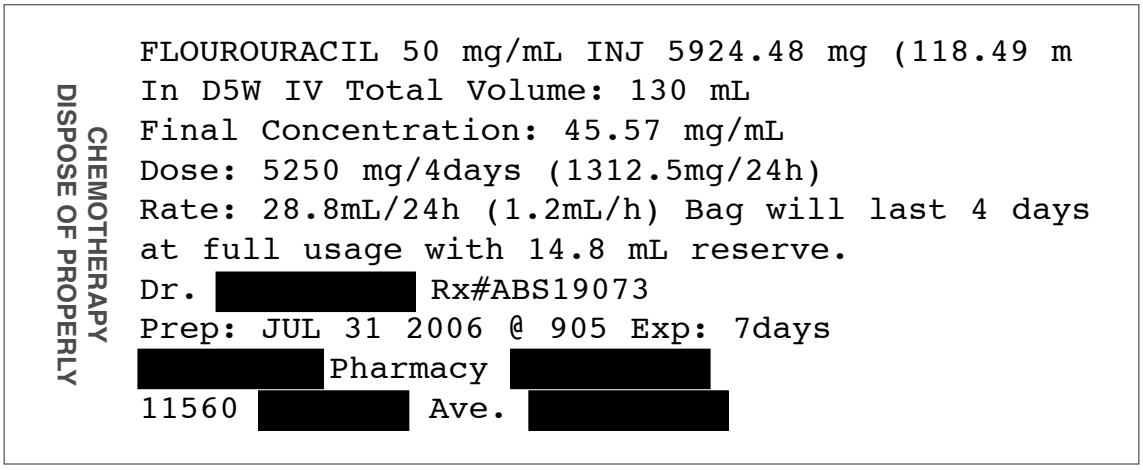

Figure 2 The drug bag label. The black regions are obscured in the root cause analysis to preserve anonymity. The figure accurately reproduces the text, including character spacing, line breaks and font (the text "ABS19073" – that S might be a badly written 5 – and the "905" were written by hand, and JUL 31 2006 was rubber-stamped). The first line ends "m" as the original label was not long enough to print more; possibly "L)" has been omitted. Note that the label refers both to days and to units of 24h. Since the patient can read this label, it might have been helpful to say, "Bag will last 4 days at full usage with 12 hours reserve", rather than "14.8 mL reserve", which in itself is not very useful information.

it should have been 1.2 mL per hour. However, their independent calculations agreed and thus their errors weren't noticed; moreover the incorrect number they calculated, 28.8 (in units of mL/24h), was written on the bag label, which itself would have misleadingly helped to confirm their calculations.

The patient left the centre, and returned later, surprised that their bag was empty several days earlier than usual. They had had an overdose from a chemotherapy drug delivered 24 times too fast, and unfortunately later died from the drug's effects. That is the story in brief, though it does not cover related issues such as the problem of managing an overdose from a drug when the hospital has no overdose protocol. Nor does it cover the social consequences on the nurses' lives, nor whether anybody learns the best lessons, rather than blaming individuals.

What we are interested in here are the specifically IT aspects of the situation, and whether IT helped or hindered. Unsurprisingly, the root cause analysis was not written by IT experts, so it ignores these issues. For example, the nurses made a calculation error. What type of calculator did they use? This isn't a clinical issue, so we do not know – but it might matter.

Please look at figures 1 and 2, which show the actual information given to the nurses. From these figures, work out what dose to give the patient. There are many questions: why are there two separate pieces of paper, and why

are they so complex, providing confusing details the nurses do not need to know. The patient name or identifier is not present on either label. The cancer centre knows the patient is using an infusion pump calibrated in millilitres per hour, so why isn't the correct value printed? Actually, the correct value (1.2mL/h) is printed, so there is clearly no statutory reason to keep it a secret to force the nurses to check it independently, but it was printed along with many inappropriate values such as 28.8mL/24h (which could be written more clearly as 28.8 mL per 24 hr).

Next, we can ask, given that for some reason the nurses are supposed to calculate a drug rate, what are they supposed to do? For clarity, figure 3a presents all the numbers and units printed on the labels; figure 3b presents just those that are required to perform the correct calculation. Apparently, the nurses are to perform the calculation based on the numbers 5250 mg, 45.57 mg/mL, and 4 days to get a rate in millilitres per hour. The correct calculation is (5250/45.57)/(4×24). To do this on a typical calculator without brackets requires this exact sequence of 22 keystrokes:

AC MRC MRC 4 × 2 4 M+ AC 5 2 5 0 ÷ 4 5 • 5 7 ÷ MRC =

There are three obvious problems with this: first is that the sequence of keystrokes bears little relation to the original sum. Calculators are hard to use! Secondly, calculators are different (even look-alikes from the same manufacturer), and while this is correct for one calculator, it may not be the correct sequence to use on a different calculator: it may give a different answer on another (for example, if its memory has to be cleared by pressing **AC** twice). Thirdly, any slip will simply give a different result, without reporting an error.

All numbers and units as printed	Numbers actually required by nurse
5,250 mg 4,000 mg/m2 **4 days** 1000 mg/m2/day 4000 mg/m2/**4 days**	5250 mg 45.57 mg/mL 4 days (answer 1.2 mL/h also printed)
50 mg/mL 5924.48 mg 118.49 m 130 mL **45.57 mg/mL** **5250 mg/4days** 1312.5mg/24h 28.8mL/24h **1.2mL/h** **4 days** 14.8 mL reserve 905 Exp: 7days 11560	

Figure 3 The numbers required for the nurses' calculation. Figure 3a (left column) shows all numbers and units taken from the labels (see figures 1 and 2); numbers required for the calculation are highlighted. Figure 3b (right column) summarises the numbers actually required for the calculation. Note that the label already shows the correct answer (along with incorrect answers).

The calculator has no idea what sum it is supposed to be doing; it can do anything, so it will happily produce any answer whatsoever (Thimbleby, 2000; Thimbleby, 2008).

The last point is not unique to calculators but pervades IT. We know that all humans will eventually make slips. With the calculator – and with the infusion pump the nurses were using – obvious slips like keying in too many decimal points are misinterpreted, and not even reported to the user as errors for them to notice and sort out. This practice of imagining that users are perfect pervades IT, and is reinforced with the unfortunately common attitude that only imperfect people make errors. Rather than design good systems, then, both IT and healthcare too often conspire to scapegoat the "bad" user rather than supporting them (as illustrated at the end of this article) – ironically in an area known to have continual opportunities for human error!

In fact, the calculation can be simplified, for instance to

AC 5 2 5 0 ÷ 4 5 • 5 7 ÷ 4 ÷ 2 4 =

But there is a Catch-22: calculators are for people who can't otherwise do calculations reliably, and almost certainly anybody who

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can convert (5250/45.57)/(4×24) into 5250/45.57/4/24 will have noticed that it's approximately 5250/45.57/100 = 52.50/45.57 ≈ 1.1 anyway. People like that won't have many problems with calculators or checking their results. User centred design would suggest that expecting users to do this task (especially when it could be computerised away) is unreasonable: why should nurses have to work out how to do sums to suit the IT rather than just do them anyway? Solving unnecessary technical puzzles takes time away from patients.

Given that calculators seem to be so hazardous, particularly for healthcare professionals, it seems that their use in hospitals persists merely because of misplaced awe of IT. As thirteen clinicians wrote in a refereed paper published in the Journal of the American Medical Association, "Computerized approaches are ideal for [eliminating error] because reliability can approach 100%, while methods that rely on human inspection will always miss some errors." (Bates et al, 1995). The sentiment is fallacious, on at least two grounds. Consider: the reliability of paper can approach 100%, but it obviously does not follow that an organisation using paper thereby becomes more reliable. It depends on how the organisation works, what and how procedures are "paperised". With computerisation, however reliable computers are themselves, any misunderstanding of the organisation's procedures will force users to employ workarounds and hence lower reliability. Indeed, the increased fatalities reported by Han et al (2005) were because users were forced into doing what the computer system required. Secondly, comparing computerised approaches with methods that rely on human inspection overlooks that computers themselves are programmed by humans who are equally subject to error – and possibly more so, since sufficiently skilled programmers necessarily understand clinical conditions less well than the experienced users of their systems.

Just because it is amazing that calculators work at all does not mean that they are amazing in hospitals. On the contrary, it is hard to see any sensible reason for allowing them

inside hospitals given how poorly designed they are (see Thimbleby, 2000). The drug bag has already got the right answer printed on it; why did the nurses have to use an unreliable process to recalculate something already known?

It seems that healthcare has become complicated, and that IT is seen as the way to handle this complexity. It is clear that this approach to healthcare is not working well. Whatever processes the pharmacy and the infusion pump automated, they were not the right things to automate, or at least to automate in this way.

Are there alternatives? In fact there are many different alternatives. Here are a few:

- Had the drug dose been 50 mg per hour (not 54.69), and had the pharmacy diluted it to 50 mg per mL (not 45.57) the calculation could have been done in one's head: 50/50 is 1 mL per hour. It's also very easy to estimate! Or the drug could have been supplied in a 100 mL bag (not 130 mL) to last 4×24=96 hours. Again, 100/96 is very easy to estimate: it's just over 1 (in fact, it is 1.04). I'm not sure we know the patient's weight to this precision, so these approximations are probably fine – certainly the cancer centre will not know the patient's weight to four significant figures, and there is no point providing the numbers to this misleading precision; all it does it make it more likely that the numbers will be misread or miskeyed.
- The pharmacy could have done the calculation (it evidently did) and entered it on the device themselves, rather than telling nurses to redo what it could do better.
- The pharmacy could easily have printed **IMPORTANT: 1.2 mL per hour for patient XXXX** on the drug bag.
- The pharmacy presumably has a record of the patient's last dose. It could tell the nurses to continue at the same rate. The infusion pump already knows this rate.
- The infusion pump – a dedicated device in a cancer treatment centre – could have known that a dose of this particular drug (fluorouracil) of about 50 mg per day would be fatal. Well, the actual device used cannot do that, but alternative products now on the market can do "dose error reduction" checks on drugs and dosage.
- The infusion pump could have used wireless, and been directly programmed from the pharmacy, perhaps with RFID tags or bar code checks to make sure it was being used by the intended patient.
- The nurses could have asked the patient, a strategy that would be even better if they did this routinely and taught the patient the parameters of their treatment.

And so on. Alternative approaches are not at all hard to imagine, and this is without wondering about alternative treatment regimes or even pharmaceutical developments (e.g., there is currently no antidote for a fluorouracil overdose).

We could improve IT (for example, see Thimbleby & Thimbleby, 2008; Thimbleby & Cairns, 2010). What is clear, however, is that the healthcare profession is not thinking about complexity and human error and how to sort them out; instead they seem to be buying into IT "solutions" to their messy problems. In an ideal world, developers would really understand the domain, the tasks and what users really do, and, in turn, users in the domain would, with the help of developers' insights, improve their processes: it is a two-way collaboration and takes many iterations. Unfortunately, IT loves complex systems, and often helps make them more complex and more inflexible. Particularly when the IT systems are developed and used by people who do not really understand what is going on.

The root cause analysis also did a human factors study of nurses using the infusion pump. Three out of five trained nurses, following the same protocol, entered incorrect data; all five were confused by setup; two out of five were confused by programming; three out of five were confused by the decimal point (which also serves as a mode change feature on the device!). This human factors analysis took just an afternoon's work, and it revealed major flaws in the user interface design and ergonomics of the infusion pump. A general rule is that if lots of people are making mistakes (here, 60% of them entered wrong data; 100% were confused by the device), there is something wrong with the system, not with the individuals.

To my mind, these empirical results raise important questions: why didn't the cancer

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centre perform any usability evaluation of the device before it was purchased? And, if such poor usability results can be found in only an afternoon, why didn't the manufacturer do this elementary work and correct the flaws as part of their normal iterative design of the product before releasing it to market? Why did the regulatory agency approve it? The answer does seem to be that people do not understand IT systems, and one infers that while hospitals and healthcare professionals buy into IT so uncritically, manufacturers will have no pressure or motivation to do any better.

The manufacturers have everything to gain by improving their devices and solutions. They have everything to gain by better understanding the real tasks and processes that healthcare professionals perform under difficult circumstances. Or so you would think, except that manufacturers have protected themselves with legal get-outs.

In the most notorious example of this, two hospital technicians went to prison in Panama for manslaughter after a medical device they were using killed patients through an overdose caused by an undetected error (McCormick, 2004; IAEA, 2001) – in my opinion, due to a program bug. The device manufacturer's web site (Multidata, 2010) says they make "easy-to-learn and user-friendly tools with the right functionalities for effective work in the clinical routine", but in their user instructions they say,

> It is the responsibility of the user to validate any RESULTS obtained with the system and CAREFULLY check if data, algorithms and settings are meaningful, correct or applicable, PRIOR to using the results as a part of the decision making process to develop, define or document a course or treatment. In particular, a USER SHOULD VERIFY THE RESULTS OBTAINED THROUGH INDEPENDENT MEANS AND EVALUATE ANY DISCREPANCIES CAREFULLY until the USER'S PROFESSIONAL CRITERIA HAS BEEN SATISFIED.
>
> Original emphasis; quoted in IAEA (2001, p47)

In other words, why use this sort of IT system in healthcare at all? Why doesn't the IT system itself also use some "independent means" to double-check its own results?

IT (computers and complex devices) have improved the world enormously – consider aviation safety – but only in domains that are well understood. Often IT has changed domains: businesses have been transformed by the web. If IT is to realise its potential in healthcare, the manufacturers have to better understand users' hugely varied tasks including the errors and workarounds, and the healthcare profession itself needs to work out how to change and adapt to make best use of computers. That is user centred design at its best, but it seems it will require much higher quality computer scientists and human factors experts than have so far been employed: it will take hard new thinking and new research, and a real dialogue between developers and healthcare professionals. Computerising what managers (or politicians!) think we are doing at present won't work and, as is already happening, it will lead to a stand-off: where manufacturers will supply what sells, but knowing that it won't work well. They will then have to protect themselves in legal frameworks that kill the spirit of user centred design before we've even begun to see the real transformation of healthcare we all want.

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