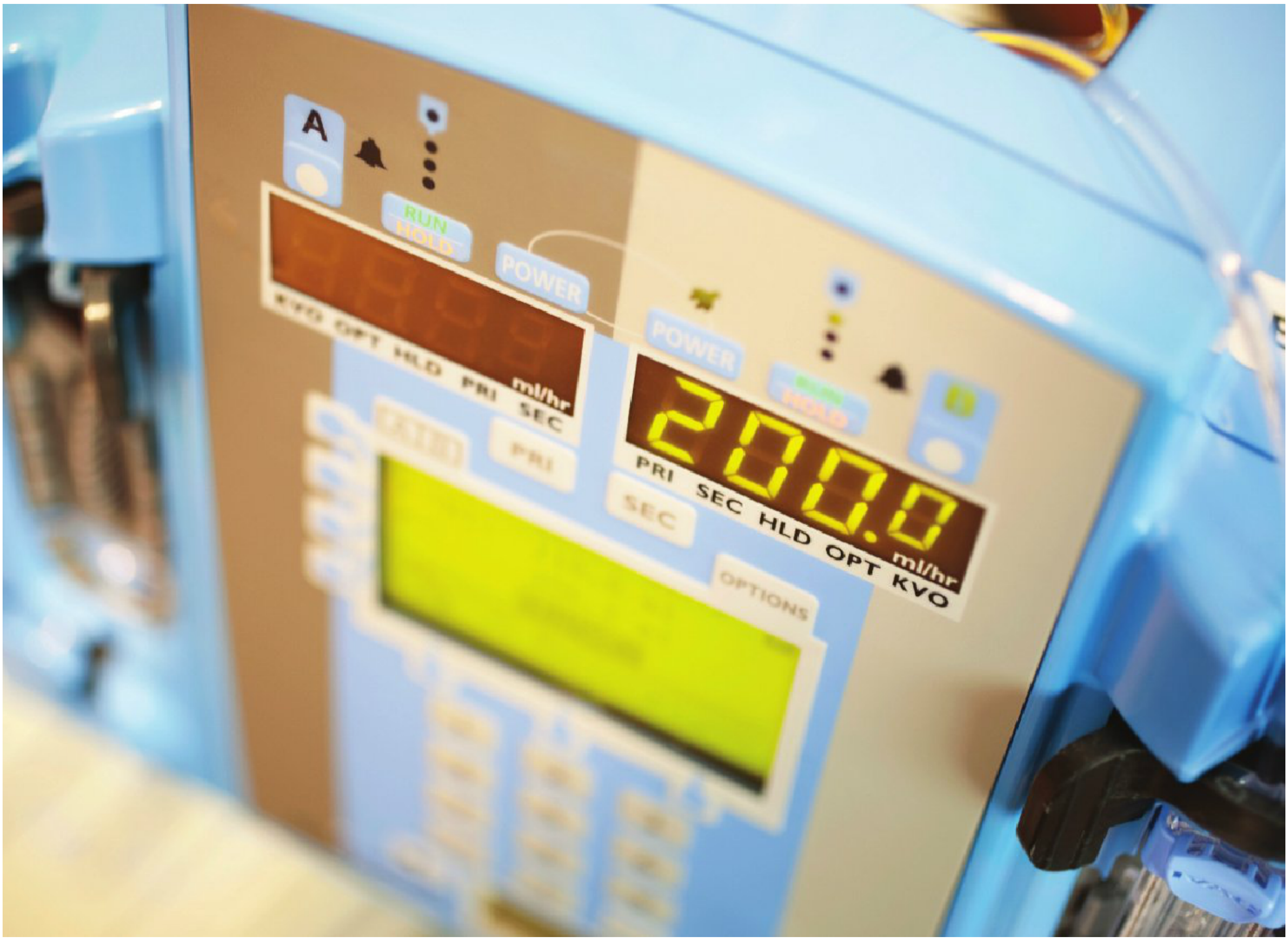
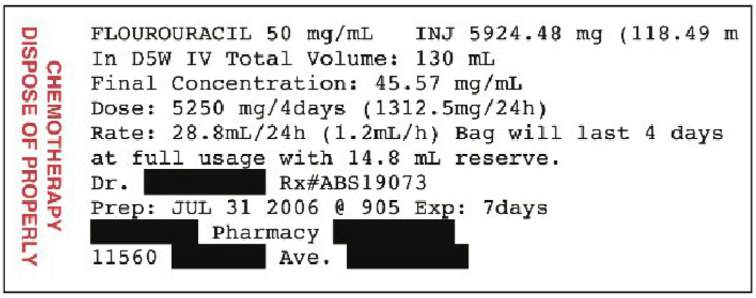



# Designing IT to Reduce DRUG DOSE ERROR

IT and medical devices with embedded computers ought to be able to reduce the number of adverse incidents currently taking place in hospitals. Using the example of an infusion pump, Harold Thimbleby of Swansea University highlights the approaches that need to be adopted to be successful in this.

Approximately one in ten hospital admissions suffer an incident as a result of human error. Calculation errors are estimated to cause 10% of preventable deaths in hospitals. It is tempting, but wrong, to automatically blame the hospital staff. Obviously, IT and medical devices with embedded computers ought to be able to help reduce calculation errors significantly.

Here are three maxims to consider. "Human error" is always an opportunity to think of ways to design technologies to reduce error. Even "simple" technology is much more complex and error-inducing to use than we like to think. Thirdly, designing appropriate technologies is the key to reducing patient harm. This article shows one way to combine the best of reliable, easy to use, low

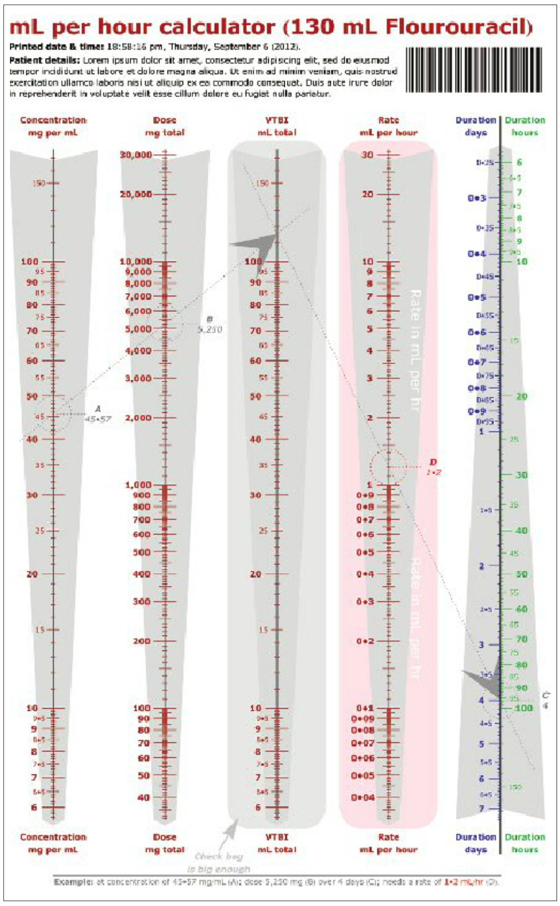


CHEMOTHERAPY
DISPOSE OF PROPERLY

FLOUROURACIL 50 mg/mL INJ 5924.48 mg (118.49 m
In D5W IV Total Volume: 130 mL
Final Concentration: 45.57 mg/mL
Dose: 5250 mg/4days (1312.5mg/24h)
Rate: 28.8mL/24h (1.2mL/h) Bag will last 4 days
at full usage with 14.8 mL reserve.
Dr. [redacted] Rx#ABS19073
Prep: JUL 31 2006 @ 905 Exp: 7days
[redacted] Pharmacy [redacted]
11560 [redacted] Ave. [redacted]

**Figure 1: Reproduction of original drug bag label from the ISMP report[1]; the black regions were obscured in the ISMP root cause analysis to preserve anonymity. The report criticises the information design: there is far too much irrelevant information, and it is not presented to make the user's tasks easy (for example, identifying the patient or calculating a rate in mL per hour)**

**Figure 2: Dose calculation using a nomogram that can be used to work out the fluorouracil dose calculation in the article. The nomogram has patient details on it and a bar code to help check the patient, drugs, route and the nomogram are properly related**




technology ideas (such as paper) with high technology ideas (such as touch screens) to reduce patient harm.

### One daily problem

Let us focus on a "simple," routine design problem, but one that is typical of broader technology design issues in healthcare and raises in a particularly clear way some of the challenges that we face. Things we take for granted in design have subtleties it is easy to miss, and if we miss these issues, we design suboptimal products.

Here is the sort of calculation some nurses do every day: in chemotherapy a patient is to be given 5,250 mg fluorouracil at a concentration of 45.57 mg per mL over 4 days.[1,2] What is the rate in mL per hour needed to program the patient's infusion pump? In a typical hospital environment these numbers have to be picked out from a complex background of pharmaceutical data printed on a drug label (see Figure 1). Poor information design makes the nurses' task harder.

Most people would use a calculator for this sort of problem. Unfortunately, using a calculator is often unreliable. If the person making the calculation makes any slip (it will take a minimum of 22 key presses on one of Casio's best-selling calculators), they will get the wrong answer, but the calculator will not notice.[3] Ironically, we tend to believe calculators, which makes it harder to notice errors (after all, we are using the calculator because we didn't know the right answer to start with!).

It is obvious that these routine calculations are so demanding that no one would be able to get them right day after day, never making a slip; it is amazing that so many skilled nurses do something so complex faultlessly all the time. If a patient is given an overdose and dies, then should we blame the nurse who pressed the button or blame the system that asks nurses to do something that no normal human can do reliably?

There are probably millions of problems that go unreported, thankfully because the patients came to no obvious harm (although they may have stayed in hospital a bit longer). Fundamentally, we are not supporting clinicians to detect and manage errors; most devices have no idea what a nurse is trying to do.

### Moving towards a solution

It seems obvious that more sophisticated "smart" infusion pumps connected to electronic patient records should be developed. Unfortunately, it is not as simple as just being "smart." There are several projects that aim to "design out error," but this is misguided; error is still going to happen, and if we have designed out error, the nurse will still be to blame! "Computerisation" in an American hospital[4] doubled fatality rates in a paediatric ward. One reason was that, effectively, every patient lost a clinician because the clinicians now had to work on a computer rather than be hands-on. Computers must be much better to compensate for these predictable costs of use!

Computerising what hospitals are currently doing will no doubt make them more efficient, but it does not address the underlying problems. People are addressing the wrong computational problems. Calculators, Excel, conventional IT and clouds are only superficial help. It is glib to say it, but we will merely have adverse incidents faster, not fewer or less harmful ones.

In the above drug dose calculation example, a simple solution would be to improve the way pharmacies tell nurses what to do. Already, the pharmacy has a computer printer. Why not use the printer to print something better designed for the nurse's task?

### The nomogram

Let us have a thought-provoking digression. A nomogram is a simple way to do a prepared calculation on a sheet of paper. All that is required is to draw a straight line on the paper. Figure 2 shows a nomogram that the pharmacy could have printed for our problem. It can be printed on waterproof paper to make it more reliable for a hospital environment. The nomogram necessarily uses the right formula for the calculation. The computer has seen to that.

The nurse can now do the calculation on paper, and another nurse can check it very easily — it is merely a matter of checking that the drawn lines are right, rather than checking that a lot of tricky calculations on a calculator are right. Then it is just a case of programming the infusion pump to give 1.2 mL per hour.

The paper record provides a powerful benefit. The record is not only the result of the calculation, it is a visual support. As the nurse slips the nomogram into the patient record folder, there will be other ones there. A glance will confirm whether the new nomogram works the same way.

It is not surprising that nomograms are used widely in healthcare. They are ideal for situations when professionals are in difficult working conditions such as in emergency departments. Nomograms even work well after they have been dropped! Experiments reported by Dave Williams et al. show that nomograms (used for complex burns calculations) are more reliable than calculators and conventional pencil and paper calculations.[5] They are faster than paper and comparable in speed to conventional handheld calculators. It is interesting that "task-appropriate" technology, even though old, can do a better job than some modern technology.

## Next generation devices

Nomograms are cheap, simple and effective; they would save lives. The only reason not to get too excited was well put by Atul Gawande in his excellent book "The Checklist Manifesto,"[6] where he writes about the WHO Surgical Checklist (another cheap bit of paper) that reduces morbidity and mortality in surgery. If something good is free, it is priceless, but also seems worthless. There is no multinational able to make a profit out of just printing bits of paper. Nomograms are so archaic, what modern pharmacy would think it an improvement to use them when it could be buying modern technology?

More positively, it is exciting to see new interactive nomograms available on the iPad[7], and it is easy to imagine them modified for use on next-generation infusion pumps and other devices with touch screens. Integration with patient records would avoid transcription errors when transferring numbers to the infusion pump. Either the pump could do the nomogram itself (perhaps in a more compact form factor, like a type of slide rule,[7] with a cursor and moving scales), or a tablet computer could wirelessly connect to the pump, thus giving the user a larger format and a mobile and more convenient display than a fixed pump offers.

One could give the drug label a QR code to specify the right nomogram for the tablet to show. The QR code in Figure 3 will download the nomogram shown in Figure 2. In that way, you have got all the benefits of paper (dependability, auditability) as well as the benefits of IT (security, automatic checks, relation to patient records).

Because each nomogram can be printed for a specific patient and dose, it can take account of patient weight and it can do a "dose error reduction" range check. Thus, it should not be possible to calculate an overdose. With the nomogram shown here, because the bag is known to be 130 mL, the total dose physically cannot exceed 130 mL, and the nomogram scale can end at 130 mL.

One is led to wonder that if dose error reduction calculations can be made by the pharmacy, then why not just print the correct answer (1.2 mL per hour) on the bag and not risk human error in its repeated calculation? Figure 3 gives a mocked-up example of an improved drug label.

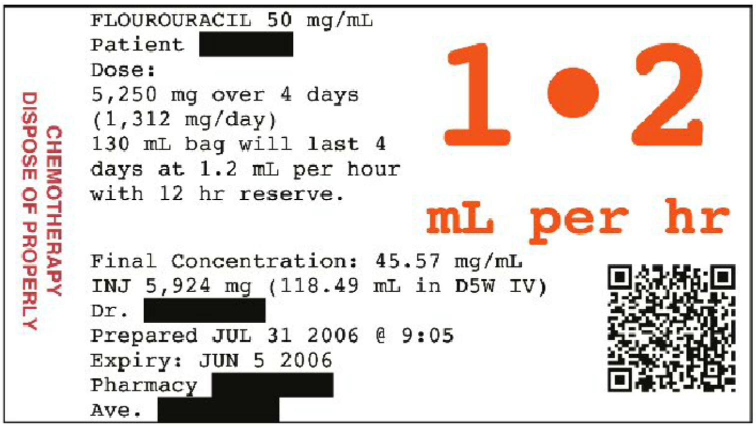



**Figure 3: Mock up of an improved drug bag label. As well as highlighting the required dose, we have made the expiry, the times etc. easier to read; we have also removed the 28.8 mL per day dose as we know the infusion pump on the ward has to be programmed in mL per hour. Depending on the therapy, one might choose to make different information more prominent; here, we have made the dose rate in mL per hour prominent, as the incorrect calculation of this rate was a factor in a fluorouracil overdose fatality[8]**

## Re-examining health IT culture

Part of the problem involved in improving health IT is that the healthcare practices and current IT supports are counter-productive to being automated. The culture needs re-examining. Figure 3 gives a simple example of how we could improve the information design of a drug label. Why was the original label so badly designed in the first place? It was not the first ever drug bag label printed, so where is the evidence of best practice? Why do nurses have to repeat a tricky calculation already done for them, and one that is disguised by extraneous and confusing information?

It is often said the problem in healthcare is the culture. But it goes deeper. The "techie" approach that wants to solve problems with "off the shelf" computers and clouds etc. risks solving the wrong problems and leaving the deeper ones untouched. It is important to analyse the tasks that are actually being done, then investigate how to improve them to align with what computers do best. But merely computerising what is going on is a recipe for disaster. It should be like business re-engineering, but now we call it user centred design; see reference 8 for a fuller discussion and brief introduction to ISO 9241, the relevant standard for user centred design.

## Building a better future

What we can hope for is that one day in the future, if we are lucky, we will have dependable computers properly integrated into a more effective healthcare system, and that these improvements will be evidence-based. In the meantime, who wants to put the research effort into improving things when the hospitals themselves do not demand a better system, and when technophiles think it is self-evident that computerisation means progress? Furthermore, there is considerable evidence that ignoring user centred design (that is, human factors) is a naive mistake, to say nothing of the legal requirement to follow human factors-informed international standards such as ISO 62366, Medical Devices, Application of Usability Engineering to Medical Devices.

The real problem is that when an incident occurs it is far too easy (and far cheaper) to blame the nurse who pressed “the wrong button.” The ease of ignoring root causes perpetuates the myths. We should instead be blaming the unnecessary complexity, the unnecessary design faults and, underlying it, the way we are failing to address the broader picture. If — when — we do that, the long range impact will be a reduction in the number of unnecessary hospital deaths, a rate that currently exceeds the death rate on the roads, and this objective deserves all the deep attention it can get.[9]

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