

DIGITAL HEALTH

How Technology Will Transform Medicine, Healthcare And the Doctor-Patient Relationship

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What Is Digital Health?

“The convergence of technology and biology will be the biggest innovation of the twenty-first century”

Steve Jobs, 2011

We are in the process of applying digital technology to medicine, healthcare and to our own bodies. We are harnessing artificial intelligence to improve medical diagnoses and treatment, we are using robots to look after the old and vulnerable, we are using computer power to decode our individual DNA and we are using the genomic data collected to personalize medical treatments for those who are seriously ill. By 2030 personalized medicine – i.e. treatment that is tailored to a patient’s individual biology – will be available to all.

Meanwhile, fit and well consumers are strapping fashionable wearable sensors to their wrists and their bodies to count their steps, to measure their fitness, to monitor their hearts, their breathing, their stress, their blood oxygen levels and their sleep patterns.

Soon healthy “informed patients” will also be monitoring their blood pressure, blood glucose levels and other key health indicators with the same fashionable wearable devices (without the need for cumbersome equipment or invasive blood testing).

For more than 20 years patients have been scouring the internet for clues to diagnose ailments, for information about known conditions and for general medical advice. And for over a decade patients have been connecting with other patients on social media to discuss their conditions, to compare treatments, to review and rate doctors and hospitals and to receive invaluable support from their peers. Patients now belong to networks.

Consumers who need instant medical advice can now consult doctors virtually using an app on their smartphones. For a small monthly fee, or for a one-off payment, patients can talk via video apps with qualified doctors who are able to issue prescriptions and make referrals. Traditional health service structures and formalities are being bypassed.

Pharmaceutical companies are using digital technology to monitor patients and to record data on drug performance in real world conditions. The new insights such data offers allows drug researchers to improve drugs and to invent new treatments – and to test them more effectively, under more realistic conditions, than has ever been possible before.

Long after other professions, industries and business sectors have been transformed by the internet and digital technology, medicine is finally feeling the full force of the digital revolution.

In terms of improved human health, wellbeing and longevity – surely the most important metrics of human existence – this marks a major “inflection point”.

Every so often there are such step changes in human progress, a point at which technological development seems to flex and twist before spurting forwards in a completely unexpected direction.

The invention of electricity was one such inflection. The achievement of powered flight was another, nuclear weapons another, and then computers and television were invented.

In recent decades personal computers, the internet and mobile phones have in turn changed the world and the path of progress.

Following each point of inflection there are scores of sub-developments, each significant in their own field. The development of smartphones in combination with the internet and cloud data storage has caused major disruption in multiple industries: banking, hotel keeping, taxi services, airline bookings, publishing, newscasting, television, car making, insurance, etc.

Now we are starting to add digital sensors to our bodies, to interrogate their inner fitness and health. Computers are being used by laypeople and medical professionals alike to aid diagnosis both of trivial conditions and life-threatening diseases. Electro-Cardiogram machines (ECG units) are now appearing as inexpensive, ultra-portable accessories for smartphones allowing heart patients to monitor their own cardiac rhythms during their daily lives and, when necessary, to instantly send the results to their heart specialist for interpretation (basic interpretation can now be done by the patient).

Low cost, hand-held ultrasound scanners are also available as accessories for smartphones and pregnant women can now watch their babies movements in real-time in the comfort of their own homes. Sports medics, trainers and coaches can make preliminary checks on injuries incurred at the sports field, track gymnasium or pool.

Robots have long been used in operating theatres to carry out precision surgery, but as the cost of robots falls dramatically and their functionality increases, more and more operations are now being carried out by machines working under human supervision. When robots are used as aids to surgery, operations are usually completed with precision, miniaturization, smaller incisions, decreased blood loss, less pain, and quicker healing time. Crucially for hospitals, in-patient stays are reduced.

Digitally-controlled 3-D printers are now manufacturing custom-made replacement bones, body parts and prosthetics – manufacturing those parts in locations close to patient-recipients (e.g. in hospitals) – and providing these rapidly and at far lower cost than traditional medical manufacturing techniques,

Everything about medicine and healthcare is being disrupted by digital technology.

Changing the Doctor-Patient Relationship

Because of the internet and digital technology the knowledge that was once the sole property of doctors and other medical professionals is becoming democratized and from now on patients will be much better equipped to monitor their daily health and to work to actively preserve and cherish their most precious and important asset: “wellness”.

This polemic on digital health *does not* suggest doctors are no longer necessary – quite the opposite. But the health-monitoring technology, communications infrastructure and rich store of medical knowledge and support now becoming available to ordinary people will, in time, redefine the role of both patients and doctors. This process will free up medical professionals from some of their

basic body-monitoring and repetitive treatment duties to become more personal, more investigative and more creative in their healing and care-giving.

To be clear, the role of doctors and surgeons in dealing with illness remains paramount. There is no replacement for the relationships created between medic and patient¹. There is only a partial replacement for a small part of the knowledge that medical training provides and, above all, there is no substitute for the experience that comes with years of diagnosis and dealing with specific conditions. It is important that access to medical information is not confused or conflated with the all-important *practical* experience that doctors gain as they treat thousands of patients over many years.

However, some of the technology this book describes is intended to *keep patients out* of the doctor's surgery. Once consumers get the bug for monitoring their own fitness and health many wonder how they ever lived with such "dumb" bodies².

Not being able to see their pulse and blood pressure readings (at any time) will come to seem as strange to many health consumers as getting into a car that does not have a dashboard³. Not knowing their blood-sugar level, cholesterol reading or blood oxygen level (if relevant to your state of health) will be like embarking on a journey without a smartphone, sat-nav system or a map. It will become simply unthinkable. People will look back with amazement at the time when our bodies were not "smart" and we forced to wander the world oblivious and blind to our physical health and unaware of the ever-changing state of our bodies.

¹ The trust created between doctor and patient appears to have a powerful placebo effect. Research has shown that treatment by a compassionate, caring health professional speeds up patient recovery.

² Autodesk, a software firm in California, says it saw a "distinct change" in employees' behaviour after more than 1000 signed up to receive Fitbits. The firm found that more people walked to work or held meetings while walking.

³ There are approximately 400 sensors embedded in our cars – why haven't we got any on and in our bodies?

At a broader level, the network is becoming the doctor. As smartphones learn to diagnose illnesses by “listening” to a coughⁱ and to detect the early onset of Parkinson’s Disease by monitoring its user’s gaitⁱⁱ, we will start to turn to our smart devices and their supporting networks as our primary care resource – the first stop when we need non-emergency medical advice.

As the sensors and health-monitoring abilities of portable and wearable devices rapidly improve, and as the capabilities of internet-based artificial intelligence health diagnosis improves exponentially, a large proportion of the population will rely to an increasing extent on computer-aided self-monitoring, self-diagnosing and self-treatment for our primary healthcare needs.

Human Biology, Evolution and Our Health

Over billions of years our bodies have evolved to be robust and reliable – at least, for the first thirty years or so of our lifespan. During most of our prehistoric existence our ancestors – hominids and early humans – mated as soon as they were pubescent, had children in their teenage years and then died as grandparents in their thirties. The super-rare early human who lived to be “old” by today’s standards must have been exceptionally lucky. Evolution had no interest in any genes which promoted old age – what would be the advantage to the gene pool?⁴

Now, thanks to a wide variety of our technological developments, average human lifespan has doubled in the last 150 years. In the developed world average human life span is now being extended into its ninth decade and, towards the end of this century, the conventional view is that it is likely that many of us can expect to live to be well over 100 years oldⁱⁱⁱ. (Many futurologists – me included – think this projection is far too conservative. By

⁴ There is an evolutionary theory that about 30,000 years ago women started to live into old age to provide child-care within the family group. Prior to this point people rarely lived beyond age 30.

the end of the 21st Century current trends suggest that some younger humans living at that time will be likely to live for centuries and it will be theoretically possible to consider the possibility of extremely extended human lifespans.)

The technological progress that has increased our lifespans over the past 150 years has done so by providing us with abundant food, sanitation, warm shelter and ever-improving medical care (and a degree of control of our own biology, e.g. birth control). Social institutions such as healthcare systems, policing, the law, education and banking have also played an important role in extending life.

Now, digital technology, network communications, electronic miniaturisation, bio-sensors and micro-fluidics (devices that can analyse tiny drops of blood and other fluids) have advanced to the point where we can begin to make our bodies smart, allowing us to learn what is happening on the inside, moment by moment, 24 hours a day. This will have an even greater effect on our health and longevity than did the technological and social developments of the previous century-and-a-half.

Disrupting Doctors And Healthcare

A profound and wrenching change is already occurring in primary-level human healthcare in the developed world. Over the last 20 years the internet has made general medical knowledge available to laypeople on demand. And the knowledge that is available to lay people is now accepted to be generally reliable and is accessible in easily understandable form.

At first, family doctors (GPs) were alarmed at this development and the joke used to be that hypochondriac patients with imagined ghastly diseases self-diagnosed on the internet (cyberchondriacs) were crowding into waiting rooms to waste doctors' time. But as the internet developed the NHS and other health services and some major medical charities added carefully edited and authenticated medical information and advice. Today there is a wealth of

reliable information on almost every conceivable condition and healthcare professionals are now the first to make use of this astonishing resource. Most doctors have learned to encourage patients to research their conditions (and their general health and lifestyles) on the internet.

However, not all doctors “get it”: In 2015 The Guardian reported:

The death of teenager Bronte Doyne from cancer after she was told to stop Googling her symptoms exposes how many professionals want to ignore the advances of the information age and cling to the old power relationship between doctors and patients.

Bronte begged doctors to listen to her after online research on an authoritative US website convinced her that her rare liver cancer had returned. She died 16 months after being told she would survive. Just days before her death she wrote: “Can’t begin to tell you how it feels to have to tell an oncologist they are wrong. I had to, I’m fed up of trusting them.” Her mother described doctors at Nottingham University hospitals NHS trust as aloof and evasive.

But doctors’ monopoly on health information is truly and comprehensively over, as the following narrative article from The New Scientist makes clear:

I WAKE up feeling lousy. The app on my phone tells me I had a fitful night’s sleep, which might have something to do with it. But I feel worse than just tired, so I go to the bathroom and pee on a sensor strip. Most metabolites are fine but there’s an excess of nitrites, which could indicate a urinary tract infection.

Back in my bedroom I run more tests. My blood results tell me my vitamin D levels could be higher – but I live in dreary London, so I knew that already. My heart rate and blood oxygen are fine, though my inflammation levels are higher than normal. Then I swab my nose and the machine by my bedside takes just a few minutes to tell me what’s really wrong: I’ve got the flu. A quick look at the flu map on my phone tells me that 8 per cent of the neighbourhood has succumbed. I’m just another red dot.

The way illness is diagnosed is changing, and we are all invited to take part. Each of the technologies described above is on the market already, or will be soon – and there are a lot more where those came from.

Further, digital technology will change the way patients interact with doctors. Doctors are already reporting that patients are requesting the right to record consultations on their smartphones^{iv} and this is a practice that will increase over the years until it becomes routine⁵.

Gone are the days when patients desperately try to remember what the doctor has said during an examination or consultation and as “life logging” – the practice of routinely recording all of life’s events – becomes more and more accepted in society, so doctors should come to accept and welcome that just as all police interactions with the public will be recorded in the future, so all contact between doctors and patients will be similarly logged. These recordings will become part of patients’ digital health files and misunderstandings and errors will be reduced as a result.

Change Won’t Come Easily To The Medical Profession

However, any change to the way formal healthcare is provided will not come easily. For reasons of patient safety the medical profession is ultra-conservative: after all, the primary Hippocratic mantra is *primum non nocere* - “First, do no harm”⁶.

But it is also true to say that doctors’ unions and medical professional associations are fiercely protective of the territory occupied by physicians and health professionals and they stubbornly resist any change to the status quo. For example, in the U.S.A. and in other countries doctors’ unions are currently demanding that the existing monopoly over your personal medical information currently exercised by doctors must be maintained – even though this information “belongs” to patients.

⁵ A few GP surgeries in the UK are already routinely recording consultations.

⁶ Hippocrates was, however, also a big believer in paternalistic medicine. He advised that doctors should conceal “most things from patients”.

In 2011 the American Medical Association wrote to the U.S. Food and Drug Administration (FDA) demanding that “Direct To Consumer” (DTC) genetic testing be banned⁷. The Association demanded that all such genetic data should only be supplied to and interpreted by doctors^v. In due course the FDA did stop genetic testing for consumers in the U.S., but not before I managed to have the most useful part of my own DNA decoded.

Alarmed medical professionals all over the developed world are lobbying governments in an attempt to stop these new digitally-mediated democratic changes to healthcare, pointing out the dangers of giving patients “information they are ill-equipped to deal with”, arguing that only professionals can interpret health data successfully and, tacitly, suggesting that most of us ordinary mortals can’t really understand information about what’s happening in our bodies. As one frequently-cited scholarly research paper puts it:

Often professionals cling to power in their engagements with patients, controlling information and dismissing efforts by patients to theorise or explain their condition^{vi}.

Although there may be some advantages to the paternalistic model of the doctor-patient relationship, the self-doctor genie is out of the bottle, never to be recaptured.

But despite the resistance of the conservative medical profession, it is now becoming clear that access to medical information and health monitoring data is the right of every human. Medical power and knowledge is being transferred from the high priesthood of doctors to the great army of “unwashed” patients. Dr Eric Topol, a distinguished U.S. cardiologist and champion of digital health, recently summed up this concept in the title of his influential book, “The Patient Will See You Now”^{vii}.

⁷ DTC genetic testing typically involves members of the public taking a cheek swab of saliva and submitting it by post for DNA analysis. The results are usually available in a few weeks and are posted on a password-protected website.

One quote from that book sums up the problem:

Patients who have in-depth knowledge of their condition encounter problems when their expertise is seen as inappropriate in standard healthcare interactions.

...Of all the professions represented on the planet, perhaps none is more resistant to change than physicians.⁸

Dr Topol is a rare, but not unique, example of a medical professional who understands the implications of digital health. He and a few others realise that the medical professional faces huge disruption, but he has already identified the myriad benefits that will flow to both patients and doctors as our bodies become smart.

In time, many of the tests and checks that were once available only in a doctor's surgery or in a pathology lab will be available instantly via your smartphone and other add-on devices. And the collection of sensors on and around your body will, very quickly, develop and evolve to become an on-body health-and-fitness network which will work 24 hours a day to help keep you as well informed and as healthy as possible. Some of these sensors may be incorporated into everyday items of clothing and, eventually, into our skin and blood.

Our bodies are natural walking "event recorders" and all that is needed to tap into this resource are inexpensive biosensors to capture the data and some clever algorithms to interpret it. Suddenly a glance at the historical records of, for example, your daily activity levels, the calories you've burned each day, your sleep patterns, your long-term resting heart rate and your average blood pressure, will tell you (and your doctor) far more about your real state of health

⁸ Topol, Med p177.

or illness than any single-visit “snapshot” check-up carried out in a doctor’s surgery ever could⁹.

Until now, it has been impossible for a doctor to see how patients’ bodies behave over time (other than when a patient is confined to a hospital bed) and this new type of low-cost ambulatory data will lead to better, faster and more accurate detection of problems, diagnosis and appropriate treatment. It will improve the health of millions and today’s annual physical check-up or “exam” will be replaced by a continuous stream of real-life, real-time information from your body. (In fact, the value of the annual physical exam has now been shown to be far less than once thought and many medical professionals regard this well established procedure as worthless.^{viii)})

The medical profession has long understood the huge value of ambulatory data. However, until very recently medical equipment for capturing ambulatory recordings has been bulky and expensive. Doctors have been cautious in prescribing the use of such equipment and patients have been reluctant to wear uncomfortable systems.

Yet real-world historical ambulatory data of your blood pressure, lung-function, heart rhythm or glucose levels (just to mention a few of the measurements soon to be possible) is the most valuable information available to our physicians. Doctors can experiment with treatments – changing doses, changing drugs or withdrawing a particular medication – and get rapid, real-time feedback of how your body responds to the change (as will you).

For example, a diabetic with a real-time read-out of his or her blood-sugar level on a smartphone can see instantly how a meal, or a certain item of food or drink, affects body glucose¹⁰. This has a powerful and instant modifying effect on diet

⁹ It has long been accepted by medical professionals that the gold standard for blood pressure determination is a small number of clinical measurements made at relatively infrequent intervals.

¹⁰ The accuracy of such consumer test results is vital to safety and medical acceptance.

and behaviour and, first the first time, provides the patient with the feedback necessary to take moment-to-moment control and manage the condition. If you know that eating a ripe banana increases your blood-sugar (glucose) reading 30 minutes later by an unwelcome 0.25 mmol/L (millimoles per litre), you might either avoid that fruit or pick a less ripe banana in future¹¹.

Devices that monitor our sleep – wristbands, smartphones, under-blanket sensors, etc. – are already providing insights into conditions and diseases that could be gained in no other way. One tagging device that was originally designed to keep tabs on offenders has shown that patients with Parkinson's Disease suffer episodes that occur during sleep – something that was completely unknown previously.

Instead of being “dumb” and difficult to interrogate, our bodies will soon become “smart” and transparent recorders and reporters of physiological data. This is a most profound change in medicine and in human health-care. As *The Economist* puts it (using the phrase “m-health” for mobile health):

Just as a car's electronics tell a driver about its condition, so m-health devices and apps “give people dashboards, gauges and alarm signals” that make it easier for them and their doctors to track what is happening with their bodies. This may alert them to the need for action well before the patient's condition deteriorates to the extent that he needs hospital treatment. Given that in America the average cost of a night's stay in hospital is almost \$4,300 (rather less at £225 in the British NHS^{ix}), there is scope for significant savings.^x

And as the Huffington Post reported:

Some technology companies have risen to the challenge with new products. Patient-consumers can purchase headsets that measure brain activity, chest bands for cardiac monitoring, motion sensors for seniors living alone, remote glucose monitors for diabetes patients, and smart diapers to detect urinary tract infections.

¹¹ Alphabet/Google has partnered with a number of manufacturers of “continuous blood-glucose monitors” to produce small wearable devices for this purpose.

Based on data from electronic sensors that track internal body temperature, another innovation sends female users a text message when it's their optimal time to conceive a baby. A large tech company's research arm is pilot testing an anti-shake spoon to counteract the tremors caused by Parkinson's disease and is working with another company to develop glucose-measuring contact lenses for patients with diabetes.

Currently, you can monitor hypertension with a blood pressure cuff or your glucose levels with a finger prick. But in the future, smart phones and other connected devices might do this automatically, alerting you, your family, and your doctor if there are significant changes if you are sick. New technologies are even being developed that will measure bodily changes from the inside out - using chips that are ingestible or float in the bloodstream.

Soon our physicians will be able to have real-time reports on the condition of all their many patients as they go about their daily lives. This data will stream wirelessly into the cloud (accessible from doctors' surgeries) 24 hours a day and, even though our doctors will not be able to monitor such individual information streams personally, their own automatic-monitoring computer systems will alert them to any of the data that requires their urgent attention.

It may seem fanciful today, but it will not be long before most informed patients over 50 (and many younger patients) will have smart bodies which are permanently connected and continuously streaming data to their doctors' offices (and to their own cloud-based storage systems).

(The key phrase in the last paragraph is "informed patients" because it is clear that there are a large number of patients in the general population who simply don't want to take any responsibility for their own wellbeing. In fact, the members of this group have little interest in their own health, other than when they are suddenly debilitated and need immediate assistance. Health professionals estimate this group to be as large as a third of the overall population with the other two thirds showing varying degrees of interest in

health which range from minimal to deeply engaged¹². Whether the disinterested 33 percent will become more interested in their own health when monitoring devices are very cheap – or even provided free of charge – is doubtful, But the impact of digital health on healthcare and social economics of the more interested majority still remains profound.)

Health data collected from patients as they go about their daily lives (“ambulatory data collection” – ADC) is an entirely new phenomenon. Until now, doctors and medical researchers have never had the opportunity to “watch and listen” to the way human bodies perform over the long term.

The volume of data streaming from health wearables worn continuously by tens of millions of people will be vast, but “Big Data” analytic data-mining tools have now been developed which will help researchers make sense of these huge pools of biometric information.

A completely new field of “predictive medical data mining” will develop as researchers identify data sets that provide early warning of physiological trouble ahead or indications of disease as it develops. We have never previously had long-term cardiac data from humans as they pursue their daily occupations (and as they sleep) and it is highly likely that researchers will develop algorithms to automatically identify the first signs of impending cardio-vascular and heart problems.

Similarly, medical researchers have never had long-term logs of sleep patterns, breathing rates, blood pressure, blood-glucose levels, stress levels, etc. A whole new horizon of predictive medicine is coming into sight and this will turn the low-cost sensors that we will wear on our bodies, that will be incorporated into clothing and that will inhabit our bathroom scales and other devices around our

¹² A major piece of American research recently reported that 50% of patients do't even their medications as prescribed, although disinterest in health and inadequate health literacy were only two of a number of factors contributing to this lack of treatment adherence.

home, car, school and workplace into massively powerful early warning systems for human health.

Another super-valuable by-product of widespread ambulatory population monitoring will be that this ADC data becomes available to pharmaceutical companies. At present, drug companies test new drugs in what are supposedly rigorous clinical trials and then have to wait a long time for real-world semi-anecdotal feedback (usually provided by doctors in second-hand descriptions) as the drug enters use in the general population. If the drug companies were able to directly access ambulatory data from those using their drug in the real world, imagine the improvements that might be possible to guidelines for use and even to the drug itself.

It's Been A Long Time Coming

Medicine has been slower than other sectors to feel the full force of disruptive digital technology. Whilst everyday activities such as shopping, banking, flying, TV viewing, music purchasing, hotel accommodation – even taxi hiring – have already been disrupted and transformed by smartphone apps and online services, most medical consultations and procedures still take place in doctors' surgeries and in hospitals as they have for the last century.

Disruption will be forced on the medical profession by external forces over which regulators, doctors and doctors' associations are powerless. Currently, patients typically present themselves to health professionals only after the symptoms of ill-health are well advanced. They are then treated with costly medicines of uncertain benefit, often using the long practised, and outdated, “one-size-fits-all, one-dose-fits-all” approach to treatment (often derided as “one size fits none”)¹³.

¹³ In the West the prevailing approach to prescribing drugs is almost unbelievably “scatter gun” and wasteful in its approach. A number of studies suggest that 80% percent of patients do not respond to the ten most often

Traditionally, healthcare has been a slow moving industry; witness the ten to fifteen year development cycles in pharmaceuticals, the immense difficulty of pushing reform through politically sensitive health systems, the cautious nature of regulators and the previously discussed nature of the ultra-conservative medical profession¹⁴.

It may be said that whilst change in traditional healthcare proceeds at a rate similar to the speed of continental drift, digital and internet developments occur at a speed which seems to be closer to the speed of light. The two do not appear to be compatible, and something has to give.

However, these formerly separate sectors (medicine and information technology) are now converging rapidly and a number of very powerful outside factors will ensure that it is medical tradition that has to give way.

The super-powerful external factors that will shake and reshape medical practice include:

1. The rapidly ageing population in the developed world:

The Baby Boomer generation is now close to, or already in, early retirement¹⁵ and in some developed nations those over 65 will, for the first time, outnumber all other generations¹⁶.

prescribed drugs for common maladies. For a shocking insight into the real efficacy of frequently prescribed drugs, visit the "[numbers-needed-to-treat](#)" website which is run by doctors and exposes the lack of evidence-based value in many oft-prescribed drug treatments.

¹⁴ There was intense resistance from the medical profession when the stethoscope was first introduced in 1816. It took 20 years before its use was widely accepted. (Topol, Patient, 275)

¹⁵ Retirement is an outdated term and will not survive for long. We need new language to describe this period of life.

With more old people come more long-lasting, chronic diseases (now re-branded less pejoratively as LTCs – “Long Term Conditions”) and, therefore, higher healthcare costs. Around 33 per cent of the UK population now has a chronic disease^{xi} whilst 45 per cent of Americans are similarly afflicted^{xii}. The apparent difference between the two nations may be real, it may be as a result of different medical definitions in use or it may reflect the more aggressive approach to treatment typical of the U.S. health system.

All this would be good business for privately funded healthcare systems – provided patients can find the money necessary for treatment or to pay their health insurance premiums.

But for taxpayer-funded healthcare systems such as Britain’s NHS (and such national public health schemes are standard in the majority of developed societies outside of the USA) the increasing number of elderly patients and the increasing cost of healthcare technology is certain to mean more rationing of care and greater pressure on the price of drugs, and on limited medical resources.

Huge numbers of old people with chronic illnesses – those ailments that never get cured, only managed (arthritis, diabetes, hypertension, COPD, etc.) – have never existed in any society before; previously most of our older people have died before they reached the point of needing continuous healthcare. This huge elderly group of chronically ill patients

¹⁶ The problem is much worse in some nations than in others. For example, Greece has an official retirement age of 50. In the UK large-scale immigration has increased the number of families with young children and this has, to some extent, re-balanced the disparity between young and old.

will be a vast and unprecedented drain on our taxpayer-funded health systems.

2. Most countries suffer from a serious mismatch: the demand for health care is rising faster than the supply of doctors.

In the UK hospitals are facing a shortage of 20,000 doctors and nurses^{xiii}. During 2014 the UK had 2.71 practising doctors for every 1,000 people – fewer than all other European countries including Bulgaria, Estonia and Latvia^{xiv}.

In the USA the Association of American Medical Colleges predicts a shortage of 45,000 primary-care doctors by 2020, precisely the type of doctor who might manage the chronic conditions of the elderly^{xv}.

There's a similar shortage of doctors in Germany and it is estimated that by 2020 in Europe as a whole, 230,000 doctor's roles and 590,000 nursing positions will need to be filled. In less than a decade, there will be a professional shortfall of 1 million jobs in the European health sector (including all roles).

3. The rapidly escalating cost of healthcare treatment:

Dedicated, high-end medical technology is tremendously expensive and drug development is becoming ever more lengthy and more costly (resulting in ever more expensive drugs)^{xvi}.

It may seem strange that whilst other areas of technology development such as computers and televisions results in better products at lower costs,

this axiom does not hold true in healthcare. The main reason for the extra costs is the expense of carrying out ever more complex clinical trials and the investment involved in clearing multiple regulatory hurdles. Health equipment and drugs have to be *proved* to be reasonably safe before they can be used on the public (which doesn't necessarily mean they are also effective).

In the UK the annual budget for the NHS is £95.6 billion^{xvii}.

In the USA, the annual healthcare budget is \$2.8 trillion^{xviii}.

The vast disparity in these figures is not explained by the fact that America's population is five times larger than the UK's. If population numbers alone made the difference the US healthcare budget would be \$650 billion not \$2.8 trillion. As US surgeon Dr Atul Gawande explains in his book "Being Mortal" on the US healthcare system, "If terminal patients – rather than insurance companies or the government – had to pay the added costs for the treatments they choose instead of hospice, they would take the trade-offs (between the cost and the extension of life) into account more. Terminal cancer patients wouldn't pay \$80,000 for drugs, and end-stage heart failure patients wouldn't pay \$50,000 for defibrillators offering at best a few months extra survival."

4. The method of funding used by most public and semi-public healthcare systems:

Most national public healthcare services – like Britain's National Health Service – are funded directly by the taxes paid into the scheme by the working population (in the UK they're known as National Insurance

contributions). There is no “pot of money” saved up over time – each year the costs of the health service are paid directly from the taxes received from the population.

This is a giant “pyramid scheme” as it relies on more and more people joining the programme and paying tax contributions for the system to provide more and more services to those who need it. As joining is mandatory under law for working people, there would be nothing wrong or illegal with such a scheme *if* the tax-paying population was still growing. The problem in most developed nations is that the working population is shrinking even as the retired population is growing. Fewer people are paying into the scheme whilst more and more people are requiring ever more expensive treatment. The potential for collapse is clear.

As the world knows, the American healthcare system is a total mess, despite Barack Obama’s heroic attempts at marginal reform (and the failed attempts at reform made during the Clinton Administration of the 1990s). Accordingly, Americans pay significantly more for prescription drugs and medical devices than patients in the rest of the world and the American private insurance-based system rewards doctors for carrying out unnecessary procedures^{xix}.

As things stand, Dr Atul Gawande has summed it up: “The soaring cost of healthcare has become the greatest threat to the long-term solvency of most advanced nations, and the incurable (chronic elderly) account for a lot of it”^{xx}.

So, it is clear that there are four major reasons that will force healthcare systems in the developed world to embrace patient empowerment: the ageing population, a shortage of medical professionals, the rapidly escalating cost of specialist medical-treatment technology and the method by which health systems are funded (by pyramid/Ponzi schemes).

Is Digital Health A Solution To The Health-Care Crisis?

Is there a solution to such a serious set of problems? Patient empowerment through the use of the internet, digital technology, low-cost bio-sensors and direct-to-consumer DNA analysis will ease the burden on national health systems. Even if only 20 percent of patients used new technologies to take more responsibility for their wellbeing over the next ten years, the burden on doctors' offices and hospitals would be substantially reduced.

As explained in the Huffington Post:

Today's wired consumers will become co-creators of their medical history and futures. Patient-generated data will flow into interoperable electronic record systems, and physicians and other health care providers will have new tools to better diagnose, treat, prevent, and educate their patients about many diseases remotely. With apps and social media, friends and family can play a vital role in disease management and prevention.

mHealth is an interdisciplinary space. Digital health innovations can help promote healthy lifestyles, detect medical problems earlier, enable timely treatment, connect with friends, family and community resources, with the goal of better health outcomes and a greater emphasis on home and community based care.

Additionally, these technologies can serve as a key ingredient in fuelling a prevention revolution by helping ignite a culture of health in our country and worldwide.

But beyond personal health technologies, the answer to the myriad problems facing out national healthcare systems, almost everyone agrees, must be

innovation *within* the health systems. From improved drug development and disease diagnosis to the way care is provided, new ways of managing public health are needed. The shape of a more efficient health landscape is slowly coming into view *and digital technology is at its heart.*

ⁱ <http://www.health24.com/Medical/Cough/About-cough/New-app-diagnoses-your-illness-when-you-cough-into-your-smartphone-20150722>

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<http://www.csie.ncku.edu.tw/~klan/data/paper/pdf/Early%20Diagnosis%20of%20%20Parkinson's%20Disease%20using%20a%20Smartphone.pdf>

ⁱⁱⁱ <http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf>

^{iv} <http://www.medicalprotection.org/uk/practice-matters-issue-7/digital-dilemmas---patients-recording-consultations>

^v <http://www.wired.com/2011/02/american-medical-association-you-cant-look-at-your-genome-without-our-supervision/>

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^{vii} <http://www.amazon.com/The-Patient-Will-See-You/dp/0465054749>

^{viii} http://www.nytimes.com/2015/01/09/opinion/skip-your-annual-physical.html?_r=0

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http://www.institute.nhs.uk/quality_and_service_improvement_tools/quality_and_service_improvement_tools/length_of_stay.html

^x <http://www.economist.com/news/business/21595461-those-pouring-money-health-related-mobile-gadgets-and-apps-believe-they-can-work>

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^{xii}

http://www.fightchronicdisease.org/sites/fightchronicdisease.org/files/docs/GrowingCrisisofChronicDiseaseintheUSfactsheet_81009.pdf

^{xiii} <http://www.telegraph.co.uk/health/healthnews/10551257/NHS-hospitals-suffer-staffing-crisis-on-top-of-scandals.html>

^{xiv} <http://www.telegraph.co.uk/health/10550335/UK-has-fewer-doctors-per-person-than-Bulgaria-and-Estonia.html>

^{xv} <http://www.economist.com/node/21556227>

^{xvi} <http://www.scientificamerican.com/article/cost-to-develop-new-pharmaceutical-drug-now-exceeds-2-5b/>

^{xvii} <http://www.england.nhs.uk/allocations-2013-14/>

^{xviii} <http://www.economist.com/news/business/21595461-those-pouring-money-health-related-mobile-gadgets-and-apps-believe-they-can-work>

^{xix} <http://www.forbes.com/sites/robertpearl/2014/04/24/americas-broken-health-care-system-the-role-of-drug-device-manufacturers/>

^{xx} "Being Mortal", Dr Atul Gawande, Profile Books 2014.