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Forecasting, uncertainty and risk; perspectives on clinical decision-making in preventive and curative medicine

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ABSTRACT

Should we screen the population routinely for the presence of breast or prostatic cancer? This simple proposition masks a landscape of complexities, including the economics of screening, the prevalence and probability of the disease, desired frequencies of intervention and a willingness to adopt preventive screening. These 'risk factors' form part of a broader landscape of uncertainty that characterises the intricacies of clinical decision-making. Deepening our understanding of the way in which clinicians evaluate risk and uncertainty requires a framing of insights into language, communication, psychology and epistemology. This paper explores perspectives in forecasting and uncertainty as a basis for understanding individuals' perceptions of risk when assessing their options in both preventative and curative medicine. At the heart of the issue is the prevalence of diagnostic error; this paper argues for the use of systematised approaches to medical error management and inclusive approaches to research in the field. The advantages of augmenting the management of unforeseen consequences through an improved understanding of the issues that are of concern to patients, carers, and medical practitioners alike forms a key construct in this paper. We conclude with an exploration of potential opportunities for improvements in medical practice: changes that may reduce the disbenefits of uncertainty and enhance the management of the general risks associated with clinical decision-making.

1. Introduction

The diagnosis of disease and the prescription of appropriate courses of action is a decision-based problem that is characterised by risk, uncertainty and complexity. This perspectives paper explores the 'anatomy' of clinical decision-making through the lens of complexity theory, in an attempt to understand how clinicians conceptualise a course of action through a cognitive evaluation of its benefits and disbenefits to patients. Almost all clinical decisions involve an element of forecasting; the clinician formulates

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hypotheses regarding the presence of a disease, the potential outcomes of a prescribed course of action, and the uncertainty and risk that are present in the decision variables. By implication, practitioners should understand the level of uncertainty that is associated with a given course of action. Equally importantly, clinicians should seek to understand how their cognitive biases and epistemological position might influence their evaluation and communication of risk when enacting clinical decisions. This paper examines the evidence related to the forecasting of risk and uncertainty within the context of clinical decision-making. We therefore make a series of evidence-based recommendations with the aim of improving the way in which risk uncertainty and complexity are communicated, including suggestions for future research.

The American College of Preventive Medicine defines the goal of medicine as being "*to protect, promote, and maintain health and well-being and to prevent disease, disability, and death*".[1] The focus on preventative medicine in the United States (US) can be traced back to the introduction of annual generic health examinations in the early 1920s, an approach that remains the predominant instrument of preventive health today. However, various studies in the 1960s suggested that such examinations were of no clinical benefit other than to reduce patient worries (Boulware et al., 2007). This exacerbation of anxieties that may be experienced by patients undergoing routine screening has led to the emergence of the term 'worried well'. Reinforcing this point, Glasziou, Moynehan, Richards, and Godlee (2013) argue that medicine is increasingly so pre-occupied with managing the 'worried well' that its resources are often stretched and unable to meet the needs of the genuinely sick. This sentiment was echoed by Krogsbøll, Jørgensen, Grønhøj Larsen, and Gøtzsche (2012), who concluded that general health checks do little to reduce morbidity or mortality, such that some national expert panels advocate that they should no longer be recommended as part of contemporary practice.

We illustrate the notion of complexity and uncertainty in relation to the management of risk in clinical decision-making by considering some of the evidence that is available to guide physicians when they are informing patients of the benefits and disbenefits of routine screening for cancer. The diagnosis of breast cancer in females and prostatic cancer in males forms the basis of the case studies presented in this paper.

1.1. Breast cancer screening

A frequently recommended preventive test for breast cancer is mammography. Mammography involves the use of low-dose X-rays to assist with the early diagnosis of patients who present with the symptoms of breast cancer, if no other detectable symptoms are present. From 2003 onwards, the American Cancer Society recommended annual screening for all women over 40, for as long as they remained healthy.[2] However, the US Preventive Service Task Force (USPSTF) now recommends biannual mammography for women aged 50 to 74, whilst also advising women to avoid self-examinations.[3] Similarly, the UK recommends mammography for women over 50, as the breast is less under the influence of the menstrual hormones, and thus it is easier to establish whether a true lump exists or not. However, not only is mammography in isolation not a wholly accurate method of detecting the presence of breast cancer (Sui, 2016), it also involves a significant cost: the data suggest that in 2010, $7.8 billion was spent on mammography tests in the US alone (O'Donoghue, Eklund, Ozanne, & Esserman, 2014).

A number of studies have sought to quantify the benefits of mammography. For example, Gøtzsche (2012) argues that mammography reduces breast cancer risk by one third, and the independent review of the literature by the Independent UK Panel on Breast Cancer Screening (2012) shows a small absolute reduction in mortality rates as a result of screening. However, Harding et al.'s (2015) study of almost 60,000 women across the US refutes Gotzsche's findings, instead concluding that mammograms lead to over-diagnosis. Gøtzsche (2012) also highlights the potential harms that can arise due to over-diagnosis and overtreatment.

Perhaps driven by the inconclusive nature of the debate regarding the benefits of mammography, one recent addition to the breast screening armoury is digital breast tomosynthesis (DBT), a tool which produces images that are similar in both quality and definition to CT scans (Diekmann & Bick, 2011). This relatively novel screening process is showing encouraging results, particularly in women with dense breast tissue, among whom it is especially difficult to accurately distinguish breast abnormalities using traditional or digital mammography techniques, leading to more recalls (Takahashi, Lee, & Johnson, 2017). DBT highlights genuine tumours more clearly than other screening tools, meaning that recalls and false positives are less common and patients experience better health outcomes (McDonald et al., 2016). As DBT is still in its infancy, its efficacy as a viable and reliable diagnostic option is yet to be verified. Nevertheless, McDonald et al.'s (2016) three-year study comparing digital mammography with DBT showed promising results, although both the long term impact of DBT on patient outcomes and its ability to arrest the disease trajectory need further evaluation.

1.2. Prostatic cancer screening

In the same way that screening tools are designed to reduce the risk of fatal breast cancer in women, the prostate-specific antigen (PSA) test is designed to reduce the number of fatal prostatic cancers in men. Up to 52% of men undergo PSA testing annually, at a cost exceeding half a billion dollars for US Medicare patients alone (Ma et al., 2014). As with breast cancer, numerous studies have presented cases for and against screening, drawing conclusions that are broadly similar to those outlined above for breast cancer. Ablin (2014) argues that PSA tests are 'marginally more

[1] See http://www.acpm.org/?page=WhatisPM.

[2] See https://www.cancer.org/healthy/find-cancer-early/cancer-screening-guidelines/chronological-history-of-acs-recommendations.html.

[3] See http://www.uspreventiveservicestaskforce.org/Page/Document/UpdateSummaryFinal/breast-cancer-screening.

useful than flipping a coin', and concludes that such screening serves only to increase the numbers of tests and prostatectomies undertaken, in order to prevent US urological practice from going out of business – and this in spite of the USPSTF[4] arguing against PSA-based screening for prostatic cancer irrespective of age (Ablin, 2014). Although PSA screening has declined rapidly since 2012, when the USPSTF recommended against its use for routine screening (Hall et al., 2017), the European Association of Urology[5] has continued to bemoan the endless debate regarding the benefits and disbenefits of PSA testing. Instead, the EAU champions the need for targeted rather than widespread screening for prostatic cancer (Heidenreich et al., 2014).

Arguably, preventive screening requires a fundamental rethink in order to help manage uncertainty and the potential for people to make the wrong decision (Schroder et al., 2009). In the absence of definitive evidence, uncertainty and risk abound, especially for those who must decide whether or not the benefits outweigh the potential harm incurred by over-diagnosis and/or overtreatment. Thus far, the narrative suggests a clear need for some form of preventive medicine, but we argue for a re-examination of the evidence, particularly in view of the emergence of new diagnostic tools. However, this must not either worry the well unduly or neglect those who genuinely require preemptive interventions. The potential for new biomarkers based on genomics and DNA testing is gaining traction in the research community, with the detection of prostatic cancer via urine testing emerging through the advent of the Prostate Cancer Antigen 3 (PCA3) biomarker.

In a systematic review examining the relative efficacy of PCA3 and PSA for detecting prostatic cancer, PCA3 was found to be a better diagnostic marker than PSA (Luo, Gou, & Peng Huang, 2014). Nevertheless, some studies have shown conflicting evidence. Hence, further research is needed to establish whether this genetic biomarker is reliable across a broader population of men over time, before it can become the screening tool of choice should it prove effective. Thus, due to the inconclusivity of the current research, the National Institute for Health Care Excellence (NICE) in the UK does not currently advocate routine PCA3 testing for those who have had a questionable or negative prostatic biopsy.[6] Hence, this diagnostic option is currently offered in only a small number of centres, located largely in the private health care sector.

Another contemporary approach to screening for those with non-aggressive prostatic cancer is where the patient, in collaboration with their physician, elects to delay undergoing surgery in order to avoid the risk of incontinence or erectile dysfunction: a form of screening known as active surveillance. According to Bayliss, Duff, Stricker, and Walker (2017), active surveillance as a mode of disease management is the option of choice for those preferring to engage in active or collaborative decision-making, although physician advice is still the most powerful decision-making influence (Bayliss et al., 2017).

Overall, only time will show whether any of these new diagnostic screening tools and/or options will become the new panacea. At present, there is no conclusive evidence to support forecasts of any significant benefits, nor is it yet clear whether such tools will increase or decrease diagnostic errors. Until then, physicians and patients alike will have to play a waiting game, pending evidence to either confirm current theories or reveal that the new modes of screening equate to nothing more than the 'emperor's new clothes'.

2. Forecasting the effects of curative medicine

Clinical decisions are made within an environment of risk and uncertainty, where forecasts of the likely benefits of a particular course of action are made but will not always be reliable. Hence, clinicians face a challenge in balancing patients' desires for certainty with accuracy in an environment that is often characterised by high levels of uncertainty. Notwithstanding the debate on screening processes in curative medicine, there are four interrelated steps to each successful treatment episode, namely:

1. Making the correct diagnosis at the outset.
2. Choosing the treatment location, namely hospital- or home-based.
3. Determining the most appropriate treatment, the proper dosage of medication or the correct intervention.
4. Taking the prescribed medication or following the treatment plan.

Within the curative health context, some risk factors are outside the physician's control; for example, when a patient succumbs to a superbug infection or fails to adhere to or comply with their prescribed medication regime. However, the following sections aim to examine each of these four steps in more detail.

2.1. Correct diagnosis

The last decade has seen rapid advances in techniques that can assist with diagnoses, including the wider availability of laboratory testing, the development of equipment such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography/Computed Tomography (PET/CT) scanners, and, as highlighted above, the emergence of new diagnostic screening tools. Nevertheless, despite the evidence suggesting that diagnostic error rates are reducing, 5% of patients seeking outpatient care still experience missed diagnoses (Balogh, Miller, & Ball, 2015). When misdiagnoses occur, patients endure unnecessary suffering and/or life-threatening complications (Kliegman, Bordini, Basel, & Nocton, 2017). Misdiagnoses or a lack of a diagnosis leads to avoidable diagnostic or invasive procedures, which not only exacerbate suffering and expose patients to added complications, but also increase the financial burden on patients and health care systems alike (Kliegman et al., 2017).

A US study examining the outcome of medical referrals when a diagnosis was uncertain found that the original diagnosis was confirmed in only 12% of cases. Encouragingly, in 66% of cases, the diagnosis was merely defined

[4] See https://www.uspreventiveservicestaskforce.org/Page/Document/UpdateSummaryFinal/prostate-cancer-screening/.

[5] See http://uroweb.org/european-views-on-psa-screening-debate/.

[6] See https://www.nice.org.uk/guidance/dg17.

more clearly. However, in 21% of cases, the final diagnosis was radically different from the original (Van Such, Lohr, Beckman, & Naessens, 2017). These findings confirm those of Meyer, Singh, and Graber (2015), who looked at patient-initiated second opinions in the US and found that the second opinion resulted in a change in the diagnosis for 15% of patients. However, 37% of patients experienced a change in their treatment, and, more significantly, 10% of patients had a change in both their diagnosis and their treatment plan.

Statistics regarding diagnostic errors tend to refer to averages for all diseases. However, unsurprisingly, there are distinctions in the number of errors arising if we classify cases as easy or difficult. Meyer, Payne, Meeks, Rao, and Singh (2013) point out that there is a substantial level of uncertainty associated with the diagnostic process, given that 118 physicians within the US diagnosed easy cases correctly only 55.3% of the time. However, more worryingly, this accuracy level dropped to only 5.8% when the physicians were presented with difficult cases.

What is perhaps more disturbing still is the issue of physician confidence that they are doing the right thing when they are faced with "easy" or "difficult" cases. The findings of Meyer et al.'s (2013) study highlighted the fact that physician confidence levels changed very little regardless of whether they were confronted with easy or difficult cases. For example, physicians ranked their confidence as 7.2 out of 10 when faced with easy cases, and 6.4 out of 10 for difficult cases. Thus, even when their diagnostic accuracy was as low as 5.8%, they were still confident that they had made the right diagnosis 64% of the time.

In terms of decision-making, a low diagnostic accuracy of 5.8% could be tolerated if the physician was only 10% confident of being right. If such were the case, the physician could order more tests, re-evaluate the symptoms, or ask for a second opinion from a peer to improve their chance of making a correct diagnosis. However, having a physician feel confident that a diagnosis is correct 64% of the time will preclude their seeking a second opinion, thus reinforcing their conviction that they were correct in proceeding with a given treatment, despite it being based on a wrong diagnosis, the consequences of which could be harmful for the patient (Van Such et al., 2017). This is further confirmed by the findings of Cassam (2017), who argues that physician overconfidence is a major factor contributing to diagnostic errors in medicine.

2.2. Treatment location

Once a diagnosis has been made, regardless of whether it is correct or not, the next consideration is the treatment location. Where would be the best place to administer an intervention: at home or in hospital? The most appropriate treatment location will depend on both the diagnosis and the type of treatment needed to ameliorate the problem. Hence, the diagnosis, treatment option and location are all inextricably linked, and, as Meyer et al. (2013) showed, if any one of these elements is wrong, it will have a negative impact on the overall patient outcome.

2.3. Most appropriate treatment (after the diagnosis)

After reaching a diagnosis, a physician must rely on current accepted practices and evidence-based literature, including clinical guidelines, to help steer the decision-making process for selecting the most appropriate treatment plan in order to determine the best way to cure the "diagnosed" disease. Again, this process is not without risk, as there are two diametrically opposed issues that can arise when physicians follow recommended treatments. The first is referred to as "medical reversal", which is where "*a currently accepted therapy is overturned* [but the new treatment is] *found to be no better than the therapy it has replaced*" (Ioannidis, 2005a; p. 11; see also Coccheri, 2017). Worryingly, medical reversals account for 40% of what physicians do, particularly when up to 40% of treatments are untested and/or do not work. Thus, Prasad and Cifu (2015) argue that medical reversals are "*one of the most important problems in medicine today – if not the most important*" (p. 205).

The second problem concerns the contemporaneous nature of the available evidence on which physicians base their practice; the nature of the medical research literature is such that new information, knowledge and theories can often contradict and/or invalidate the present wisdom. Ioannidis (2005b) articulates a growing concern that a significant proportion of modern research in medicine may be based on false findings (Leek & Jager, 2017). If such an hypothesis proves correct, the probability of patients receiving the correct treatment is potentially still lower. Fatovich and Phillips (2017) have added to this debate by controversially suggesting that medicine's continued reliance on the significance of the p-value in research is compounding this issue. Hence, there needs to be a careful and unbiased reflection on the results generated by research.

From an epistemological perspective, there are two critical questions that must be asked at this point. First, how are patients assured that medical practices will not be reversed in the future; and, second, how can medical research be utilized as a basis for treatment when future studies could invalidate existing recommendations? Clearly, physicians can only practice medicine on the basis of the current best evidence, and nobody can blame them if such treatments are later proven to be ineffective or harmful. However, this uncertainty increases the risk of a wrong treatment either having been given, or potentially being applied in the future, such that patients may be better off forgoing the offered medical intervention at the outset.

2.4. Risks associated with the prescribed medication or treatment plan

Treatment plans are not always foolproof, and therefore they are frequently associated with errors, particularly when medication or invasive interventions are required. In the period since 1999, the estimated number of medical errors *per se* in the US has increased steadily, from an initial estimate of 98,000 per year (Allen & ProPublica, 2013; Kohn, Corrigan, & Donaldson, 2001) to 180,000 in 2010 (Wilson, 2010), while a more realistic estimate in

2013 indicated that around 400,000 US patients suffered some kind of preventable harm contributing to their death each year (James, 2013). The latter study reported that serious errors were 10 to 20 times more prevalent than fatal ones (James, 2013). Serious harm and/or death in hospital can be caused by various "never events", such as (a) surgical instruments unintentionally being left inside the patient, (b) performing the wrong procedure, (c) operating on the wrong surgical site, (d) or operating on the wrong patient. Whatever the exact figure, the fact remains that preventable medical errors are the third leading cause of death in the US, after heart attacks and cancer, and present a major risk to patients' lives and wellbeing (Makary & Daniel, 2016).

3. Reducing medical errors and patients' risks

The 1980s and 1990s saw an expansion of the total quality management movement within Japanese and Western-style industries that decreased the number of defective products in circulation dramatically, to less than one in a million, by drawing on the six sigma approach to quality improvement (Deming, 1986; Juran & Godfrey, 1998). Following Chernobyl and numerous aviation disasters, a route case analysis approach to error management started to emerge. Since then, similar approaches have been applied to medical practice (De Jonge, Sint Nicolaas, Van Leerdam, & Kuipers, 2011). However, one major problem with using such approaches to medical error management is that errors *per se* need to be reported before any attempt to investigate their origins, and therefore eradicate them, can commence.

Returning to the main focus of this paper, namely diagnostic errors, the prevalence of such errors remains unknown, although autopsy data suggest that they account for 10%–15% of all errors, which suggests that if 400,000 errors occurred in 2013, at least 40,000 of these constituted diagnostic errors (Cassam, 2017; Graber, 2013; Singh et al., 2013). However, Bordini, Stephany, and Kliegman (2017) suggest that the number of diagnostic errors could be even higher, at approximately 17%. These latter forms of error are considered attributable *a priori* to human rather than systems errors, and one way of exploring this in more detail so as to be able to unpick the problem would be for physicians to report errors as part of their reflective practice.

However, initiatives encouraging the open reporting of errors have met with mixed success, due to the fear of litigation, which compels physicians to hide rather than reveal their mistakes. Blendon et al. (2002) report state that 86% of physicians surveyed believed that hospital reports of errors should be kept confidential, while only 23% backed the reporting of mistakes to a state agency. Furthermore, one of the most striking findings of the survey was that physicians disagreed with national experts regarding the effectiveness of many of the proposed solutions to the problem of medical errors (Blendon et al., 2002). Encouragingly, more recently the entreaty for greater levels of openness has started to gather pace, as has the call for physicians to be courageous, open and willing to disclose their vulnerabilities (Foster & Klein, 2016).

Similarly, various studies have offered specific advice as to ways of reducing medical errors, such as providing practitioners with checklists to guide them through the key steps involved in complex procedures (Bordini et al., 2017). Others have recommended the use of physician huddles as a means of auditing unexpected diagnoses, so as to reduce the risks associated with medical practice (Foster & Klein, 2016). Conversely, Chiozza and Ponzetti (2009) proposed the Failure Mode and Effect Analysis (FMEA) approach to error investigation, a model that was used originally in the aerospace industry to reduce prospective high-risk processes. In contrast, Sax et al. (2009) recommend team training for medical personnel in order to improve their performance, thereby reducing errors. Thus, the challenge is to identify and implement simple interventions with the potential to substantially reduce preventable diagnostic errors, thereby enabling practitioners to focus on eradicating both these errors and more serious ones.

4. Conclusions and directions for future research

This paper has shown that uncertainty is associated with the subjectivity linked to the use of preventive and predictive tests, given that they are not always sufficiently sensitive to achieve an accurate diagnosis. The latter is particularly true of traditional mammography and PCA testing. Moreover, incorrect diagnoses, inappropriate treatments, medical reversals, and practitioner competency, coupled with a practitioner's knowledge and understanding of the patient's medical history, all add to the risks and uncertainty involved in seeking medical assistance to manage the diseased body. However, perhaps the biggest risk involved in managing health is the unavailability of high quality, accurate decision-making data.

Cochrane, a global network of researchers, practitioners, patients and carers from over 130 countries, is currently working to produce credible, accessible health information that is free of commercial sponsorship or other conflicts of interest.[7] This collaborative venture aims to encourage medical and health researchers to cooperate with each other in order to improve health and wellbeing, and ultimately patient outcomes.

Nevertheless, risk and uncertainty is compounded within contemporary medical practice by the need for physicians to work under pressure and with increasingly stretched resources in the face of progressively complex cases (Zavala, Day, Plummer, & Bamford-Wade, 2017). Hence, today there is an even greater need for fundamental change to take place within medical practice itself, so as to enable physicians to implement sound clinical judgement and reasoning in order to achieve optimal patient outcomes (Cooke & Lemay, 2017). For example, patient assessments need to take place in a context of uncertainty, given that there is still significant doubt as to the correct diagnosis, investigation, or treatment of the case, as was highlighted above; so much so that it should be acceptable to arrive at more than one 'correct' answer (Cooke & Lemay, 2017, p. 746). Hence, the concluding section of this paper

[7] For more information, see Cochrane's website: http://www.cochrane.org/about-us.

explores some possible transformations in order to reduce the impact of risk and uncertainty, whilst also making recommendations for healthcare improvements, as well as for future medical practice and research.

4.1. Suggestions for patient-oriented improvements

- *Education*: patients need to be empowered to understand the capabilities and limitations of modern medicine, particularly when presenting with complex medical problems. This is not easy, given practitioners' propensities to 'bombard' patients with information that may champion the benefits of preventive medicine, with little reference to the harm it may cause. Intuitively, prevention makes sense – if discovered early, a disease can often be treated, thus reducing the risk of a serious longer-term illness. However, the balancing act needed to recognise the benefits and disbenefits of preventive care must be acknowledged. Consequently, further research is required to generate an improved evidence base in order to support the use of effective screening tools that have been shown to work across a broad range of circumstances.
- *Complete/objective information*: patients need to be informed fully about the benefits and disbenefits of medical care in a simple but informative way, so as to enable them to rationalise the medical risks involved in a given treatment from independent sources, rather than solely from physicians (McDowell, Rebitschek, Gigerenzer, & Wegwarth, 2016).
- *Rational decision-making by avoiding biases and hype*: patients need to feel comfortable with identifying the point in time at which they are satisfied with the quantity and quality of information that is available to them. Hence, patients need to be able to decide for themselves what course of action they feel best suits their circumstances. For some, the best course of action will be to seek out the maximum possible amount of information for themselves. For others, it will involve being guided by their physician, as they will not feel able to weigh up the full range of uncertainties and risks associated with their case as part of an autonomous action.

  Thus, decision-making will depend very much on the individual's intellect and cognitive biases, as these are the factors that will ultimately dictate how much information the individual is willing or able to interpret and/or use as part of their decision-making endeavours. Consequently, patients need to be invited to examine the available research-based evidence that supports their diagnosis/treatment plan and to be informed as to whether there is consensus about the proposed course of action, so as to help them avoid the biases and limitations that characterize human decision-making (Kahneman, 2011). However, when making decisions about potential preventive measures or accepted treatments for a disease, the path to such conclusions needs to involve a dualistic partnership between the patient and the physician.

  Although at present physicians do not necessarily willingly provide patients with the full extent of the information that they need to make a decision, as it increases both the patient's consultation time and any concomitant costs, it is no less than patients deserve. Moreover, physicians need to take note of the Declaration of Helsinki's (1996) notion of informed consent, namely that a person is not fully consenting to an intervention if they do not fully comprehend what it is that they are consenting to. Thus, it is vital that patients be given information in a form or format that enables them to digest the key concepts that need to be understood if they are to make collaborative, yet appropriate decisions regarding any treatment or preventive healthcare options.

Thus, governments also need to take a stronger stance to reduce the number of unnecessary interventions and to champion the use of new drugs that better target illness or supersede outdated treatment options. Moreover, professional bodies need to be active in encouraging their respective members to improve self-regulation, in order to reduce the need for government intervention (Waring, 2005)—especially as the codes of professional conduct and regulations in most countries are unequivocal on the absolute necessity to provide the patient with clear and honest information (Mira, Ferrús, Silvestre, & Olivera, 2017, p. 88).

4.2. Suggestions for medical practice/research

- *Recognising and accepting the problem*: accepting that forecasting errors and uncertainty exist is perhaps the essential catalyst to introducing tangible actions that can minimise the negative consequences of uncertainty. Nevertheless, it is also important to acknowledge that physicians are only human, possessing the same cognitive limitations as any other individual decision-maker – which leads on to the second step, namely to encourage physicians to engage in reflection (Norman et al., 2017).
- *Reflection and reflective practice*: in this context, there are two fundamental tenets underpinning reflection: reflection-in-action and reflection-on-action. *Reflection-in-action* is where practitioners re-examine their actions and critically evaluate the efficacy of such actions while engaging in practice (Schon, 1984). In effect, the individual critically reviews their actions and decides how best to learn from previous mistakes, inappropriate actions, or poor decision making and move forward, so that they do not repeat the same mistakes again.

Reflection-on-action is where practitioners engage in a critical analysis of an event or incident *ex post facto*, in order to identify the lessons learnt. Arguably, both forms of reflection can be strengthened and formalised via the use of a reflective model to give structure to the person's thought processes, such as the Gibbs (1988) Reflective Cycle. However, a process of clinical supervision might be more suitable in the context of risk and uncertainty, as it empowers individuals to gain greater insight into

and better learn from events that cause them considerable disquiet. Moreover, clinical supervision would enable practitioners to reflect both in and on action, so that they could learn from the event and change their future practice (Tomlinson, 2015).

- *Rationalising diagnostic testing*: this would involve limiting the number of laboratory tests prescribed by physicians, or eliminating general check-ups for healthy people, unless there was a family history of life-limiting or life-changing disorders that would respond better if managed proactively. This would enable diagnostic tests to be targeted better so as not to worry the well unduly, whilst also reducing health care costs by removing indiscriminate and unnecessary screening practices.
- *Developing a regulatory framework for managing risk*: there is currently a lack of clear guidance as to the way in which medical risk should be managed so as to deal with the trade-off between trying to manage risk and incurring prohibitive costs. Such initiatives need to take a more pragmatic approach, and address not only safety risks and costs, but also corporate responsibility and ethical and societal concerns (Sujan et al., 2017).
- *Generating routine and open reporting mechanisms*: medical errors need to be recorded routinely in order to make it possible to identify their origins so as to find solutions and reduce or eliminate such occurrences in the future (Fox, Bump, Butler, Chen, & Buchert, 2017).
- *Improving medical research*: there is an urgent need to provide medical practice with a robust scientific basis. This is especially important given that 90% of all published materials that physicians rely on are flawed for at least one of three reasons: publication bias, the use of inappropriate or ill-executed scientific methods and the reinforcement of vested interests (Ioannidis, 2005a, b, 2016). These deficiencies effectively lead to what has been termed a *misinformation mess*, given that many physicians are not aware that the research that they read is unreliable and of questionable quality, and frequently offers no benefit to either patients or decision makers (Ioannidis, Stuart, Brownlee, & Strite, 2017). As a consequence, educating practitioners as to how to appraise correctly the reliability and usefulness of the evidence they consult is of paramount importance, given that many do not know how to engage in such practices, thereby further increasing the risks that patients face (Ioannidis et al., 2017).

Thus, risk, uncertainty and medical error reporting must all be urgently re-examined if clinical practice is to be associated with fewer hazards. The underestimation of uncertainty is a common human bias that is also present in medical decision-making. The big challenge for medical practitioners is to accept its existence and take concrete steps to minimize its negative consequences, thereby reducing medical errors and suffering, and ultimately helping to save lives.

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