

Uncertainty in health care: towards a more systematic program of research

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Abstract

Objective: To promote a more systematic approach to research on uncertainty in health care, and to explore promising starting points and future directions for this research.

Methods: We examine three fundamental aspects of medical uncertainty that a systematic research program should ideally address: its nature, effects, and communication. We summarize key insights from past empirical research and explore existing conceptual models that can help guide future research.

Results: Past research has produced valuable insights on uncertainty in health care, but important knowledge gaps remain. Bridging these gaps will require both more empirical evidence and integrative conceptual models that can orient research efforts and promote a shared understanding of what uncertainty is, how it affects people, and how and why it should be communicated.

Conclusion: Uncertainty in health care is an extremely important but incompletely understood phenomenon. Moving the field towards a more systematic program of research has great potential to advance our understanding, but will require researchers to develop consensus on the questions that need to be asked, and to work collaboratively to answer them.

Practice Implications: A more systematic approach to investigating uncertainty in health care can help elucidate how the clinical communication of uncertainty might be improved.

1. Introduction

Uncertainty is an essential aspect of human life and an integral problem of medicine. It is the single, common challenge faced by every patient who receives health care and every clinician who provides it, as well as the administrators, payers, policymakers, and researchers who deliver, finance, regulate, and study it. In every one of these diverse activities undertaken by different stakeholders, uncertainty of one form or another—arising from various sources, pertaining to any number of relevant issues, arising in mind, and formed and reformed through communication—provides the call to action, and provokes a variety of different responses [1].

Uncertainty in health care is by no means a new topic, but one as old as medicine itself [2]. Yet uncertainty in health care has grown in visibility and importance in recent years. Advances in medical science, culminating in the sequencing of the human genome, have produced an ever-expanding array of new technologies of unproven value. The evidence-based medicine movement has clarified what is known but also unknown about the benefits and harms of a growing number of medical interventions, raising professional awareness of scientific ignorance [3-6]. At the same time, a growing emphasis on patient engagement and shared decision making in health care has begun to extend awareness of this ignorance to patients and laypersons. Broadening dissemination of medical information through both traditional mass media and social media channels has extended this awareness even further, to the general public. The end result of these trends has been heightened collective uncertainty in health care.

For a problem of such integral and growing importance, one might expect uncertainty in health care to be the focus of its own systematic program of research. Certainly, the volume of research on uncertainty appears to be increasing; a PubMed literature search using “uncertainty” as either a MeSH term or a title word demonstrates exponential growth (**Figure 1**). Even a cursory survey of this literature reveals studies spanning the entire spectrum of translational research and conducted by investigators representing a variety of disciplines from anthropology to zoology. Most studies have focused on resolving uncertainty about some particular issue, rather than investigating uncertainty *per se*, as an object of inquiry in its own right. Nevertheless, studies focused explicitly on uncertainty have also grown in number and diversity.

This growth, however, belies a lack of systematicity: research on uncertainty has developed organically, in an uncoordinated, piecemeal fashion. This evolutionary path is understandable; uncertainty is a complex phenomenon with myriad manifestations, causes, and effects (**Box 1**). No single study, investigator, or discipline can capture all of its complexity. Yet the lack of systematicity also raises problems, as recent reviews of research on the nature of uncertainty and the phenomenon of “uncertainty tolerance” have demonstrated [1, 7, 8]. Diversity in research generates not only rich insights but confusion and inefficiency. The same phenomenon becomes defined using different terms, and vice versa. Important conceptual assumptions are taken for granted rather than being made explicit. Studies simply duplicate one another rather than asking and answering unique questions, and generate both false-positive and false-negative empirical findings in terms of their novelty, significance, and true

value to the field. Multiple theories proliferate, each focused on different parts of the proverbial elephant, seen through different conceptual lenses and described using different languages. Researchers talk past rather than with one another, and fail to reach a shared understanding of what is truly known and not known about the phenomenon [9].

We believe that simply maintaining the status quo only adds to the plethora of disconnected—and either redundant or unnoticed—findings, concepts, and theories, and impedes understanding. Research on medical uncertainty needs to evolve from an organic and piecemeal to a more deliberate, coordinated, integrated program of work.

Of course, absolute systematicity is an unattainable ideal. The problem of medical uncertainty is simply too complex—and the research enterprise too vast—to consolidate within one unified research program or theoretical paradigm. From a pragmatic perspective, furthermore, there is no single best program or true paradigm, only more or less useful ones. Yet we believe at least some progress towards greater systematicity is possible and necessary; the alternative is perpetual fragmentation in our understanding. Greater systematicity, however, requires meaningful consensus on basic concepts, issues, and research priorities, and collaborative engagement of the research community.

The current paper is an attempt to promote these goals. We examine three fundamental aspects of medical uncertainty that we believe a systematic program of research should address: its nature, its effects, and its communication. These questions correspond,

respectively, to three broad research questions. First, what exactly is uncertainty, and how does it originate? Second, how does uncertainty affect patients, clinicians, and other stakeholders? Third, how—and why—should we communicate uncertainty in health care? These questions, we believe, cannot be coherently addressed without a shared understanding of key concepts, issues, and priorities, and the goal of this paper is to facilitate such understanding. Towards this end, we present a selective synthesis of conceptual definitions and frameworks that we and others have developed in prior literature reviews [1, 7, 9-12]. We present these definitions and frameworks not as definitive endpoints for future research, but as provisional starting points—descriptive rather than explanatory models that can stimulate and guide further theoretical and empirical research on medical uncertainty, and engage the broader research community—including behavioral, clinical, communication, and social scientists—in these efforts.

2. The nature of uncertainty in health care

A precondition for any systematic, integrated program of research is consensus on the nature of the phenomenon of interest. Historically, the nature of uncertainty has been the province of numerous disciplines outside of health care—e.g., communication studies, economics, mathematics, philosophy, psychology, sociology—and the result has been a rich variety of conceptual models [1, 13-16]. In recent years, as the nature of uncertainty as a health care phenomenon has become a topic of investigation in its own right, more models have been added to the mix [2, 9, 17-22]. The diversity of conceptual models—which cannot be adequately summarized here—is the first problem that must be addressed in efforts to make

research on medical uncertainty more systematic. We need some level of agreement on what uncertainty represents before we can proceed with investigating how it affects people or how we should manage and communicate it.

In approaching this problem we must first acknowledge that all conceptual models are simplifying abstractions—incomplete, imperfect, socially constructed representations that reflect the assumptions and values of their creators, and serve some defined goal. From an epistemological standpoint they are neither “true” nor “false”—only more or less logically coherent or useful for some particular purpose and user. Any choice between them will always be subject to revision.

With this important caveat in mind, we believe it is possible to move towards consensus on a basic working definition and conceptual model of medical uncertainty, building on prior work. In 2011, Han and colleagues reviewed prior theoretical conceptions in and outside of health care [9, 13, 17, 23-27] , and proposed an operational definition of uncertainty as a human epistemic state consisting of the conscious, metacognitive awareness of ignorance [1]. Beginning from this working definition, they developed a conceptual taxonomy that classified the varieties of uncertainty in health care according to three fundamental, independent dimensions: 1) source, 2) issue, and 3) locus. The first dimension, *source*, encompasses 3 primary phenomena that give rise to uncertainty: probability, ambiguity, and complexity (**Figure 2**). Probability (otherwise known as “risk”) represents the fundamental indeterminacy or randomness of future outcomes, and leads to what has been termed “aleatory” or “first-

order” uncertainty; the exemplar is the point estimate of risk (e.g., “20% probability of benefit from treatment”). Ambiguity represents the lack of reliability, credibility, or adequacy of information about probability, and engenders what has been termed “epistemic” or “second-order” uncertainty. Ambiguity arises in situations in which risk information is unavailable, inadequate, or imprecise; the exemplar is the confidence interval around a point estimate (e.g., “10-30% probability of benefit from treatment”). Complexity represents features of risk information that make it difficult to understand; examples include conditional relationships, interactions, and multiplicity in risk factors, outcomes, or decisional alternatives.

The second dimension, *issue*, encompasses the substantive outcomes, situations, or alternatives to which a given uncertainty (arising from any of the 3 main sources) applies. These issues, in turn, can be classified as falling into three main categories—scientific, practical, and personal (**Figure 3**)—which can themselves be further sub-classified. Personal uncertainties, for example, can include uncertainties about personal identity, interpersonal relationships, and numerous other social, ethical, and financial issues [28-32].

The third dimension, *locus*, refers to the particular stakeholder(s) in whose minds uncertainty resides. **Figure 4** presents a schema including just two stakeholders (patient and clinician); it could be expanded to include others (e.g., family members, other health professionals, policymakers). The schema further simplifies reality in depicting uncertainty as a static, categorical, all-or-none phenomenon focused on a single issue. Notwithstanding these

simplifications, the schema illustrates how uncertainty may or may not be shared or equally distributed among key stakeholders.

We believe this working definition and three-dimensional model provides a potentially useful, logically coherent orienting framework for research and clinical practice. It can enable researchers to more precisely conceptualize uncertainty and investigate its manifestations, elemental causes, and effects. It can help clinicians to more precisely establish the diagnosis and prognosis of the uncertainties that arise in different clinical situations, and to more deliberately plan and implement interventions to manage them. It distinguishes between the uncertainty of patients, clinicians, or other stakeholders (**Figure 4**)—a situation that often arises from physicians' reluctance to disclose scientific uncertainty to patients [33, 34]. It can thus guide efforts to remediate these discrepancies by various means—e.g., decision support interventions aimed at helping patients and physicians achieve a shared awareness of what is known and not known.

Like all conceptual models, however, this taxonomy has inherent limitations. Its level of abstraction and specificity may be too high or low for any particular application. It is not exhaustive; it does not include more specific uncertainty sources (e.g., conflicting health information and scientific evidence [35]) and issues (e.g., cultural values, moral beliefs, social norms, financial and legal concerns), that may be of interest. At the same time, it makes distinctions that may be irrelevant to other users. It will thus always need to be applied flexibly—its scope expanded or contracted, its level of abstraction lowered or raised—based on

different user needs. For example, we recently applied the taxonomy to clinical genome sequencing, expanding its precision to identify specific sources and issues of uncertainty pertaining to this technology [36]. Applied in this way, the taxonomy can provide a useful starting point to understand the uncertainties manifest in specific clinical problems and has begun to be applied in this manner [36-41], although its broader value remains to be established.

Furthermore, the taxonomy is purely descriptive; it does not explain the causes of different types of uncertainty in health care, which encompass psychological, cultural, and social factors, or the processes by which uncertainty is constructed. It does, however, provide a foundation for explanatory models of these processes and the causal relationships between uncertainty and other health cognitions and behaviors. This is an important knowledge gap; of the many well-established theories of health behavior, for example, none explicitly include uncertainty—either in general or in any of its specific varieties—as a key variable [42]. These deficiencies reflect the paucity of empirical evidence on the effects of uncertainty, which represents another major research priority and the next focus of our analysis.

3. Effects of uncertainty in health care

The important question of how uncertainty affects people has been the focus of empirical research conducted mostly outside of the domain of health care by social scientists. This body of research is vast and impossible to adequately summarize here, but a general conclusion is that uncertainty is typically an aversive phenomenon. It promotes pessimistic perceptions and

judgments, negative affect, fear, and anxiety, indecision, avoidant behaviors, and information seeking. Aversion to probability (risk), ambiguity, and complexity—the three principal sources of uncertainty [1]—are well-described phenomena in many domains of life [43-53], including health care [8, 54-56], and the avoidance and reduction of uncertainty are considered fundamental needs and motivations.[57-62]

Nevertheless, available empirical evidence also suggests that aversive effects of uncertainty are not universal, but vary by source of uncertainty (probability, ambiguity, complexity) [63], as well as individual and situational characteristics. This is one of the most important tenets of Babrow's "problematic integration theory" [9, 64, 65], and its corollary argument that inattention to these moderating factors leads to overreliance on uncertainty reduction strategies, most notably information seeking [66]. Individual characteristics including age, sex, education, level of literacy and numeracy, personality traits influence people's responses to uncertainty [7, 46, 67-69]. Influential situational factors include whether potential gains or losses are stake; with potential gains, uncertainty may provoke positive emotions,[70] while with potential losses, uncertainty may foster hope.[62, 71, 72] Other situational factors, including the urgency of decision making and available time and resources for making a choice, may increase aversive responses to uncertainty.[59, 73] The importance of these various factors has been acknowledged in theoretical accounts of medical uncertainty, including problematic integration theory [9, 64, 65], Mishel's "uncertainty in illness theory,"[17, 18], and Brasher's "uncertainty management theory" [71, 74], and Afifi's "theory of motivated information management" [75, 76]. These theories posit that responses to uncertainty

ultimately depend on cognitive appraisals, which are influenced by numerous factors including the amount and type of available information, and the way in which it is communicated.

A useful construct for understanding not only the varied psychological effects of uncertainty, but individual differences in these effects, is the concept of “uncertainty tolerance” (UT). UT has been the focus of a large, diverse body of research undertaken by numerous investigators over several decades.[7, 69, 77] This research has focused largely on assessing individual differences in UT, which has been defined and measured in terms of various negative and positive cognitive, emotional, and behavioral responses. The guiding assumption has been that UT is a stable, trait-level phenomenon, and supportive evidence for this assumption has been provided by numerous studies [7, 78-81].

Yet because situational factors also influence people’s responses to uncertainty, UT is appropriately conceptualized as not only a stable trait, but a momentary state consisting of individuals’ reactions to uncertainty. We have thus proposed a more expansive, integrative working definition of UT: *The set of negative and positive psychological responses—cognitive, emotional, and behavioural—provoked by the conscious awareness of ignorance about particular aspects of the world* [7]. Building on this definition, we have developed an integrative, multi-dimensional conceptual model aimed at capturing the various cognitive, emotional, and behavioural responses assessed in past measures of UT (**Figure 5**) [7]. The model depicts UT as a reaction to the stimulus of one’s own ignorance, which must first become the focus of perception before further cognitive, emotional, and behavioural responses

can arise. The initial intervening steps from stimulus to perception to downstream psychological responses are moderated by various factors including characteristics of the stimulus, individual, and situation, as well as cultural and social factors. The fuzzy borders in the figure represent the fact that the concept of UT can encompass any or all of these steps and responses; how broadly one construes the phenomenon depends simply on one's interests.

This flexible working definition and integrative model also acknowledges the dual nature of UT as both a state (a given set of psychological responses) and a trait (a propensity towards a set of responses). With respect to the broader aim of promoting greater systematicity in research, this model also provides both a useful framework and road map for future research on the psychological effects of uncertainty. It acknowledges that these effects are not only broad-ranging and multi-dimensional (cognitive, emotional, behavioral), but both negative and positive in valence (**Figure 5**). The model includes numerous responses identified in past efforts to measure UT; however, this list is not exhaustive.

This integrative model supports a more nuanced understanding of UT—not as a monolithic, exclusively positive or negative set of responses, but a varied, adaptive mixture of both. It proposes causal relationships that can be tested and incorporated in more comprehensive explanatory models. Yet many important knowledge gaps remain. Uncertainty's many well established effects in other domains of life need to be demonstrated in the health care domain as well. More research is needed to elucidate causal connections between different types of psychological responses to different types of uncertainty (diagnostic, prognostic, therapeutic),

and the many person-level factors (sociodemographic, clinical, psychological, social) and situational characteristics (clinical circumstances, health care environment) that moderate and mediate individual responses of not only patients but clinicians. These causal connections are undoubtedly complex; cognitive, emotional, and behavioral responses to uncertainty likely influence one another, and their causal relationships are likely moderated by personality traits as well as situational factors. More work is also needed to better understand the lived experience of uncertainty, and the ways patients and clinicians deal with the vulnerability it entails [82, 83]. To what extent particular responses to uncertainty in different situations—that is, an individual's UT—can be improved is also an important research question with direct implications for patient care and medical education [7, 8, 84]. Finally, more research is needed to better understand how the interactions between patients, clinicians, and other parties—encompassing both the communication of information and the provision of emotional and relational support—influence the effects of uncertainty. A better understanding of these interactions is essential for efforts to communicate uncertainty—a final key focus area for a systematic program of research, which we will now discuss.

4. Communicating uncertainty in health care

The important practical task of communicating uncertainty has long been a central concern in applied technical fields outside of health care, including engineering and meteorology. The common need in each of these fields has been to communicate the level of scientific uncertainty about some specified outcome, so that people can take appropriate action. Probability, or risk, has been the primary language for expressing this uncertainty, and risk

communication has become an increasingly important endeavor and focus of research, which has extended to health care [10, 51, 52, 85, 86].

Yet the scope of this research has been limited primarily to the communication of “aleatory” or “first-order” uncertainty, arising from the indeterminacy or randomness of future outcomes and expressed in terms of point estimates of probability. Relatively unexplored has been the communication of “epistemic” uncertainty arising from either ambiguity (limitations in the reliability, credibility, or adequacy of risk information) or complexity (features of information that make it difficult to understand) [1, 12]. Epistemic uncertainty produces imprecision in probabilities, which can be communicated in various ways including confidence intervals or risk ranges; however, recent empirical studies and literature reviews have shown that epistemic uncertainty is rarely communicated in clinical practice or patient decision support interventions [87-90]. Emerging research, furthermore, has suggested that communicating epistemic uncertainty may reduce patient confidence, trust, and satisfaction, although these findings have not been consistent and more research is needed.[91-94] Another limitation of past research has been its predominant focus on developing alternative methods of representing probability—e.g., quantitative, qualitative, and graphical [95-100]—and evaluating their effects on risk perceptions, knowledge, affect, and decision making. Underexplored have been verbal clinician-patient communication strategies, as well as the effects of non-verbal communication on patients’ responses to risk information.

An equally important limitation of past research on uncertainty communication has been its predominantly descriptive and empirical—as opposed to normative and ethical—focus. Its primary concern has been the question of how to communicate uncertainty, as opposed to the question of whether it should be communicated in the first place, and if so, why [12]. This is arguably the most significant knowledge gap, which should ideally be resolved before—rather than after—engaging in efforts to develop and evaluate alternative methods of communicating uncertainty. Patient preferences for information about uncertainty may vary [101, 102], as may the ethical justification for efforts to communicate uncertainty in different circumstances. A logically and ethically coherent conceptual framework is needed to guide these efforts and to help determine the appropriate amount and type of uncertainty that should be communicated in particular circumstances, as well as the appropriate approaches to the task.

Zikmund-Fisher has provided a useful way to address this need: a taxonomy that maps different levels of precision in risk information to patients' needs in medical decision making [11]. Precise, quantitative probability estimates are appropriate, he has argued, when the primary need is to compare the net benefits of two treatment options, whereas imprecise, qualitative statements of possibility are appropriate when the primary need is to simply avoid surprise or regret. In similar fashion, one can devise a conceptual taxonomy that maps different uncertainty communication strategies to a hierarchy of goals. **Figure 6** presents an initial prototype that classifies uncertainty communication strategies according to different normative, decisional, general communication, and uncertainty communication goals, as well as different levels of informational precision. It clarifies the logical alignments between these

goals and strategies, and thereby sheds light on ethical trade-offs involved with different strategies.

At the highest level of the hierarchy are normative goals (patient autonomy, well-being). Logically subordinate to these normative goals are different *decisional goals* (deferral, maintenance or enactment of a particular decision), while subordinate to these decisional goals are *general communication goals* (to inform, affirm, or persuade). The ethical appropriateness of these goals is dictated by clinical circumstances and the level of evidence supporting the intervention at hand: deferring decisions and informing patients are appropriate when evidence is low, while maintaining or enacting decisions and affirming or persuading patients are appropriate when evidence is high. Logically subordinate to decisional and general communication goals, in turn, are specific *uncertainty communication goals*; informing entails increasing uncertainty, while affirming and persuading entails decreasing it. Finally, subordinate to uncertainty communication goals are different levels of *expressed uncertainty* (high or low) and *informational precision* (high or low). The combination of these factors dictates the range of *uncertainty communication strategies* for any given situation—from disclosure of no information (high uncertainty/low informational precision), point estimates of risk (low uncertainty/high informational precision), or risk ranges (high uncertainty/high informational precision) [12]. **Figure 6** indicates in bold some of the strategies that may logically align with specific higher-order goals; however, this list is neither exhaustive nor exclusive, and more empirical research is needed to map specific strategies with specific goals.

This preliminary taxonomy illustrates how uncertainty communication ultimately has instrumental value: it serves specific goals that are logically, ethically, and practically related to one another. It further illustrates that patient autonomy is not the only high-level normative goal—and respect for autonomy is not the only guiding ethical principle. Patient well-being (the focus of the ethical principle of beneficence), for example, is another important, competing goal. Of course, the relative moral weight of these and other goals in clinical care is the question that lies at the heart of many medical decision-making dilemmas. Whether patient well-being can ever trump autonomy, and whether a “soft” or “fiduciary” level of paternalism is ever appropriate, are matters of ongoing debate [103-105]. A taxonomy cannot resolve this debate; however, it can clarify the competing normative goals and ethical principles that motivate efforts to communicate uncertainty in different clinical situations.

For example, the widely promoted, idealized process of shared decision making (SDM) is justified by the normative goal of patient autonomy, the decisional goal of promoting temporary decision deferral, and the general communication goal of informing patients. These goals, in turn, entail communicating uncertainty—and with a high level of precision—so that patients can acknowledge existing equipoise and make value-guided decisions. SDM contrasts with the more paternalistic approach often undertaken in situations involving clearly beneficial interventions—which aligns with the normative goal of patient well-being, the decisional goals of either maintenance or enactment, and the general communication goals of either affirming or persuading, and either increasing or decreasing uncertainty. Corresponding communication strategies range from no communication at all—which may leave patients with either false

certainty or heightened uncertainty, depending on their existing knowledge, beliefs, and motivations—to the use of relatively imprecise representations of uncertainty (e.g., qualitative risk categories).

In real-life clinical situations, however, normative, decisional, and communication goals and strategies are not always so neatly aligned. They are logically—not causally—related and thus do not always march in lock-step with one another, but co-occur in complex ways. For example, prognostic communication to patients at the end of life is justified by the normative goal of increasing patient autonomy. However, it is often undertaken in service of the decisional goal of helping patients not to defer but to enact specific end-of-life care decisions (e.g., to discontinue cure-focused therapies). In these circumstances, accordingly, the general communication goal is not simply to inform but to persuade patients to consider alternative options. The corresponding uncertainty communication goal is thus to decrease—not increase—dying patients' uncertainty about the possibility of impending death, in order to encourage consideration of palliative vs. curative interventions. The communication strategy that logically follows is to use precise point estimates of mortality risk to convey a dire prognosis with relative certainty. The potential trade-off of this uncertainty-minimizing strategy, however, is psychological or existential distress—outcomes that may diminish patient well-being and lead clinicians to instead opt for non-disclosure of prognostic information [106-108].

This taxonomy requires further refinement and expansion to include other goals and stakeholders. Nevertheless, we believe it provides a promising approach to clarifying the complex goal inconsistencies, dualities, and trade-offs involved in communicating uncertainty in real-life clinical situations. In the case of prognostic communication in end-of-life care, for example, it reveals the fundamental tension between the normative goals of maximizing patient autonomy vs. well-being, and how communication efforts may sometimes be driven more by the latter than the former goal. But it also suggests that different goals and communication strategies, although logically inconsistent, are not mutually exclusive and might even be optimized through specific communication strategies. The critical empirical question is whether both uncertainty and the precision with which it is communicated can be optimized in a way that achieves an ethically appropriate balance between patient autonomy, well-being, or other high-level normative goals. This is an important question for both clinical care and health policy, as efforts to disseminate shared decision making become more widespread [109].

5. Discussion and Conclusion

5.1 Discussion

Uncertainty in health care is an extremely important but incompletely understood phenomenon, and we have argued that a more systematic program of research is needed to accelerate our understanding of it. We have briefly outlined some important knowledge gaps and key questions regarding its nature, effects, and communication, and have put forth a few descriptive conceptual models that may serve as useful building blocks for broader frameworks and causal theories that can help make future research on medical uncertainty more

systematic. We propose these models not as final destinations, but points of departure for such efforts. “All models are wrong, but some are useful,” as statistician George Box famously quipped [110], and we must acknowledge that our conceptualizations will always be imperfect, incomplete, and in need of constant refinement. However, we cannot make the perfect the enemy of the good; we need working definitions and shared models in order to advance our understanding in an efficient, effective, collaborative manner. This requires not a grand unifying theory of uncertainty, but a coherent framework that makes meaningful connections between models addressing different aspects of the phenomenon. Exactly what such a framework should ultimately look like remains to be seen. But its ultimate purpose is practical: to help researchers ask fruitful questions that will advance our knowledge of medical uncertainty.

Much more work, both conceptual and empirical, is needed to identify and bridge the many gaps in our knowledge. The question is whether the community is interested in engaging in this effort, and we believe that several activities may promote this cause. One is to foster meaningful interchange and collaboration among researchers with different interests and perspectives. Greater systematicity requires individual researchers focusing on different aspects of uncertainty to work together: to acknowledge—and hopefully influence—one another’s thinking, and to engage in broader scientific dialogue.

There are many practical ways of achieving this goal. Professional societies and conferences can provide opportunities for researchers to meet and engage with one another, and to

exchange ideas. The current paper, indeed, is the product of such an effort. Working groups of interested researchers can be created, as fields including engineering and computer science have managed to do, and these communities could be brought together—e.g., through virtual and in-person meetings. Finally, research funders play a critical role in influencing the direction of future work, and need to be engaged as partners in the broader effort of helping research on medical uncertainty evolve into a more systematic, integrated field of its own.

5.2. Conclusion

Uncertainty in health care is a ubiquitous, complex, and important problem that calls for a more systematic approach to investigation. Many barriers mitigate against this effort, but the stakes are too high to avoid trying: uncertainty in health care can quite literally be a life and death matter. As a first step in this direction, we have summarized key insights from past research, identified important knowledge gaps, and explored conceptual models that can help guide future research to bridge these gaps. We put forth the current paper with the hope of engaging the broader research community in this larger effort.

5.3 Practice implications

A more systematic approach to uncertainty in health care can improve the clinical communication of uncertainty by helping clinicians better understand what uncertainties exist in a given situation, how and why they should be communicated, what the consequences are of doing so, and how best to manage these consequences.

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