



Cross-disciplinary research in cancer: an opportunity to narrow the knowledge–practice gap

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ABSTRACT

Health services researchers have consistently identified a gap between what is identified as “best practice” and what actually happens in clinical care. Despite nearly two decades of a growing evidence-based practice movement, narrowing the knowledge–practice gap continues to be a slow, complex, and poorly understood process. Here, we contend that cross-disciplinary research is increasingly relevant and important to reducing that gap, particularly research that encompasses the notion of transdisciplinarity, wherein multiple academic disciplines and non-academic individuals and groups are integrated into the research process. The assimilation of diverse perspectives, research approaches, and types of knowledge is potentially effective in helping research teams tackle real-world patient care issues, create more practice-based evidence, and translate the results to clinical and community care settings. The goals of this paper are to present and discuss cross-disciplinary approaches to health research and to provide two examples of how engaging in such research may optimize the use of research in cancer care.

KEY WORDS

Knowledge translation, evidence-based practice, cross-disciplinary research, cancer

1. BACKGROUND

Health services researchers have consistently identified a gap between what is identified as “best practice” [as determined by scientific evidence, largely acquired through randomized controlled trials (RCTs)] and what actually happens in clinical care^{1–3}. In cancer, the Canadian Strategy for Cancer Control⁴ has estimated that cancer outcomes could be improved by as much as 30% by routinely applying in practice what is already known. This knowledge–practice gap

has led an increasing number of researchers to study ways to optimize the use of evidence in health care decision-making (from clinical “frontline” care to policymaking). In Canada, this emerging scientific field is commonly called “knowledge translation” (KT), although, across disciplines and jurisdictions, many terms exist to describe the process of putting knowledge into practice⁵.

Knowledge translation has been defined as the “iterative, timely, and effective process of integrating best evidence into the routine practice of patients, practitioners, health care teams, and systems”⁶. In clinical practice, many KT interventions tend to involve single implementation strategies or combinations of single strategies, such as traditional continuing medical education, educational outreach, opinion leaders, audit and feedback, and reminder systems. Numerous systematic reviews have been unable to demonstrate which KT interventions work best (or even consistently) across clinical settings^{7–9}. As a result, most researchers and practitioners agree that, despite a sizable quantity of research literature, the transfer of research findings into practice remains a slow, unpredictable, and haphazard process, with KT interventions working some of the time in some situations, but not at other times in seemingly similar situations^{10–12}.

Arguably, most traditional KT strategies have focused largely on one-way dissemination of scientific knowledge. Even many of the active strategies discussed and promoted in the KT literature^{13–15}—for example, educational outreach, opinion leadership, reminder systems—involve mainly the communication of scientific information from one person or group to another person or group, although two-way knowledge exchange can certainly occur as part of those strategies (discussion of barriers to changing practice, for instance)¹⁴. Nonetheless, this dominant approach is reflected in common KT rhetoric, wherein researchers are the knowledge “producers” and clinicians (or other decision-makers) are the knowledge “users”^{5,16,17}. Although the intention is

to facilitate evidence-based practice (EBP), strategies that focus on the transfer of empiric evidence often ignore the interests, values, and experiences of individual clinicians (and those of patients), and underscore the implicit power imbalance between producers and users of knowledge. Thus, many clinicians find KT strategies inadequate when trying to manage complex problems within the context of a patient's disease and life circumstances¹⁸. Indeed, many factors have been shown to influence awareness of, agreement with, adoption of, and adherence to evidence, including the needs and expectations of patients, the characteristics of patients and providers, the nature of the evidence and its mode of delivery, the setting or context of care, and the organizational and system constraints and enablers¹⁹. In terms of narrowing the knowledge–practice gap, one of the challenges is therefore that “most of the evidence is not very practice-based”²⁰.

Three common criticisms of EBP are that evidence is too narrowly defined, the role and value of clinical expertise are unclear and undervalued, and little attention is paid to patient preferences²¹. Those criticisms are interesting because the original^{22,23} and updated²⁴ conceptualizations of EBP emphasized the fundamental role of the clinician and the importance of patient actions and preferences. The centrality of clinical expertise in both EBP models highlights the importance of the clinician in integrating multiple sources of data (research evidence, clinical experience, patient preferences) to make informed patient care decisions. Nonetheless, the evidence base that has dominated the KT field, together with the hierarchies of evidence developed to help users appraise and integrate multiple types of evidence^{25,26}, has tended to produce knowledge that does not fit with the realities of clinical practice and downplays the role of clinical expertise and the doctor–patient relationship in evidence-based decision-making.

We contend that a cross-disciplinary approach to research^{27–30} is a potentially effective means of optimizing EBP and thus reducing the knowledge–practice gap in cancer care. Specifically, cancer research should involve collaboration and integration by members of multiple academic disciplines and non-academic individuals and groups with a stake in the research and its implications. As a result, researchers will have to move beyond their disciplinary silos and their distinctive approaches to knowledge production in an attempt to accelerate and optimize the use of research in clinical practice.

The goals of the present paper are to present and discuss cross-disciplinary approaches to health research, and to provide two examples of how engaging in such research may optimize use of research and implementation of the resulting innovations—that is, new knowledge, tools, and practices—in cancer care. By using the term “cross-disciplinary,” we refer to three different modes of, or approaches to, research:

multidisciplinary, interdisciplinary, and transdisciplinary (see Table 1 for definitions).

2. DISCUSSION

2.1 Crossing Disciplinary Silos

Historically, research has been carried out largely in disciplinary silos, wherein the concepts, theories, and methods are associated with a single discipline³². Although the boundaries separating closely-related disciplines might be arbitrarily defined and in many cases overlapping, they are generally agreed upon by the academic community and help to highlight the distinct concerns, concepts, measures, and methods associated with specific fields of study³². For practical purposes, a field of study may be considered a discipline once it achieves both identity (for example, political standing) and exchange (for example, a market for the “production and employment of students”)—in other words, once it achieves departmental status at a university³³.

Knowledge of real-world problems can rarely be captured and understood through the lens of a single discipline²⁹. A historical example of the importance of merging knowledge from various perspectives, methods, and analytic “levels” involves the modern understanding of infectious diseases. In the late 19th century, knowledge from both laboratory science and epidemiology were needed to understand and elucidate the biologic causes of disease and to move beyond a miasmatic theory of disease to the isolation of infectious agents and an understanding of how those agents are transmitted in the environment and have differing effects on various populations. A contemporary example of the futility of a unidisciplinary approach in understanding human health issues is the prevention and management of chronic

TABLE 1 Types of cross-disciplinary research, as described by Rosenfield³¹

Type	Definition
Multidisciplinary	The process whereby researchers from different disciplines work independently or sequentially, each from a discipline-specific perspective, to address a common problem.
Interdisciplinarity	The process whereby researchers from different academic disciplines work together to address a common problem, and yet continue to do so largely from their respective disciplinary perspectives.
Transdisciplinarity	The process whereby researchers from different disciplines work together to develop and use a shared conceptual framework that integrates discipline-specific concepts, theories, and methods to address a common problem.

disease. Tobacco use, for instance, is a risk factor for developing many chronic diseases, and yet tobacco use is an exceedingly complex behaviour involving “multiple influences, pathways, and interactions among levels ranging literally from cells to society over differing units of time that, depending on the focus of study, can range from seconds to years to decades over the human lifespan and across generations”³⁴. Scientific research that aims to explore the complex and interactive determinants of tobacco use and to reduce the disease burden of tobacco must span many diverse areas, from molecular biology and genetics to epidemiology and population health, behavioral and social sciences, communications and marketing, and health planning and policy. More than a decade ago, the U.S. National Institutes of Health and the Robert Wood Johnson Foundation launched the Transdisciplinary Tobacco Use Research Center (TTURC) initiative to support research that integrates concepts, theories, and methods from various disciplines and that produces knowledge across the full spectrum of basic and applied research on tobacco use and control³⁵.

The foregoing examples illustrate different types of cross-disciplinary research. In the early 1990s, Rosenfield³¹ first highlighted the differences between the three modes of cross-disciplinary research: multidisciplinary, interdisciplinarity, and transdisciplinarity. The multidisciplinary that led to improved knowledge of infectious diseases a century ago is perhaps the minimal requirement for addressing human health problems and accelerating improvements in practice and policy today. Indeed, health issues such as disease prevention, chronic disease management, and personalized medicine will likely require that researchers overcome their tendency to stay within disciplinary silos and adopt more collaborative (interdisciplinary and transdisciplinary) approaches to scientific discovery and application.

In recent years, others have clarified and refined the concept of transdisciplinary science, referring to a new mode of knowledge production that also includes the participation of non-academic stakeholders—for example, clinicians, patients, health managers and planners, policymakers, and community organizations^{20,36–39}. The role of the non-academic stakeholders is to contribute their specific expertise before and during the research process^{20,37}. The value of transdisciplinarity is to “ensure that one identifies and solves ‘real-world-problems,’ as opposed to such problems remaining isolated in the ‘ivory-tower’ of self-contained academia”³⁶. The basic idea is that attention must be paid to the current realities of clinical practice. By doing so, focus can be brought to bear on solving patient care problems and translating what is learned to clinical and community care settings, rather than on filling a gap in the scientific literature.

The notion of co-producing knowledge has emerged in *KT* discourse as “mode 2 knowledge

production”⁴⁰ and “integrated *KT*”⁴¹. Gibbons and colleagues⁴⁰ described mode 2 knowledge as an emerging form of knowledge produced within the context of application and thus much more context-sensitive, problem-oriented, and socially engaged than knowledge produced within the context of academic disciplines (“mode 1 knowledge”). Integrated *KT*, which originates from the Canadian health research landscape, refers to research that is shaped by researchers and anticipated “research users” alike, with the expectation that the findings will be more relevant to and more likely to be adopted by research users⁴¹. Mode 2 knowledge production and integrated *KT* are both characterized by much more active involvement of all key stakeholders in the research process, including development of research priorities and questions, collection and analysis of data, and dissemination of results. These modes of knowledge production are closely related to action-oriented or community-based participatory research, which have a longstanding tradition of knowledge co-construction by some combination of researchers, people affected, and decision-makers who can act on the issues under study to maximize the relevance and actionability of the research findings^{42,43}.

Integrating clinical knowledge, values, and experiences into the production of scientific knowledge may address many of the criticisms of EBP, facilitate the creation of practice-based evidence, and thus potentially optimize the use of research in clinical practice. For example, clinicians (and policymakers) who are expected to use the results from RCTs for decision-making are often not confident in the relevance and applicability of those studies to real-world patients and settings⁴⁴. Indeed, a mismatch between use of most trials by clinicians (to inform decisions about patient management) and the design of the trials (to test a causal relationship between an intervention and some physiologic outcome) means that many clinicians are left without direct evidence to inform their patient care decisions⁴⁵. The broader use of pragmatic RCTs^{44–46}—which recruit typical participants from heterogeneous practice settings, use a broad range of outcome measures, and select clinically relevant comparators—may help to alleviate concerns about the applicability of RCTs to everyday practice^{47–50}, provide evidence that is more relevant to patients and clinicians, and thus be better equipped to inform real-world clinical decisions. For the areas of care in which RCT designs have been widely criticized (surgery, for instance^{51,52}), research designs have to be refined and innovative tools developed to address specific shortcomings in methodology (single-institution studies and difficulty in standardizing procedures, for example). Overcoming such concerns and designing more relevant, pragmatic trials will undoubtedly require cross-disciplinary dialogue and participation. In addition, applying scientific evidence to real-world practice

will require knowledge of the important contextual factors (time, resources, incentives and disincentives, organizational constraints and enablers) that influence the ability and willingness of clinicians to capture, share, and apply knowledge in practice.

The shift toward inter- and transdisciplinary research is undoubtedly occurring in some areas of health research. In Canada, for example, the Canadian Institutes of Health Research have launched various strategic funding initiatives to facilitate interdisciplinary and transdisciplinary research that addresses priority areas of the health system such as palliative and end-of-life care⁵³, access to quality cancer care⁵⁴, and community-based primary health care⁵⁵. Those strategic initiatives, in addition to standing programs such as the Partnerships for Health System Improvement grants⁵⁶, have required the support or integration of non-academic stakeholders in the research process. In the United States, the Roadmap Initiative of the National Institutes of Health contends that the extent and complexity of current biomedical problems requires that researchers break down disciplinary silos and explore new models of team science⁵⁷. Indeed, many National Institutes of Health institutions and private U.S. foundations (for example, the Robert Wood Johnson Foundation and the MacArthur Foundation) are sponsoring inter- or transdisciplinary teams and networks.

Given the evolving research landscape, it is important also to attend to the science of the new endeavors. For instance, transdisciplinary team science is in an early phase of development and continues to lack an agreed-upon definition, with substantial debate about whether distinct differences actually exist between interdisciplinary and transdisciplinary research⁵⁸. Thus, making conceptual and operational distinctions between the cross-disciplinary approaches to scientific inquiry and evaluating the processes, outcomes, and value-added contributions of inter- and transdisciplinary collaboration pose considerable challenges^{34,58,59}. Researchers have begun to study the processes and outcomes of transdisciplinary research teams, but the value-added contributions both to scholarship and to health or health systems may not be evident for decades⁶⁰. Rigorous evaluation of the short- and long-term outcomes of inter- and transdisciplinary collaboration is increasingly important, given the substantial time and effort collaborations of this kind take and the considerable resources allocated to such endeavors in recent years.

2.2 Transdisciplinary Approaches in Cancer Research

Cancer is a complex disease and its care and treatment are likewise complex. Indeed, the management of patients with cancer commonly involves multiple providers from different organizations and health

care sectors, with the specific settings and care processes dependent on disease site, stage, and other histopathologic and molecular characteristics. At the same time, innovations in screening, early detection, and treatment modalities have the capacity to reduce mortality and morbidity from cancer; however, those innovations are not always applied in clinical practice. Worldwide, it has been estimated that one third of cancer cases could be prevented and another one third cured if practices consistently complied with the best available scientific evidence⁶¹. The growing incidence and prevalence of cancer⁶² combined with the variations and gaps in care reported across Canada^{63–74} emphasize the need to optimize EBP in cancer care.

As knowledge about cancer diagnosis and treatment continues to grow at an astounding rate, the current challenge is how to optimally bring biomedical discoveries to cancer clinical trials (translational science) and how to apply and integrate sound evidence in everyday clinical practice to improve patient care and outcomes (knowledge translation)^{75–77}. Transdisciplinary science is one way to address both challenges. But what exactly does it mean to integrate multiple academic perspectives and other types of knowledge, interests, and values into the research process, from knowledge production through to its application? In the subsections that follow, we provide two specific examples of the potential of transdisciplinary science to help optimize the application and use of new scientific advances in cancer care.

2.2.1 Personalized Medicine

The complexity of clinical practice and the difficulty of moving research findings rapidly into patient care necessitate new approaches to basic biomedical science and clinical research²⁷. An example of an area in which transdisciplinary scientific collaboration is warranted is personalized medicine.

Advances in molecular and genetic biology have led to a much better understanding of cancer—most importantly that the same disease, defined by clinical presentation, often has multiple underlying causes. The implications are that treatments should be guided not only by clinical presentation, symptomatology, and histopathologic characteristics, but also by information about changes at the molecular level that are specific to each patient. The result of this personalized approach is that clinicians ought to have a greatly enhanced ability to identify patients who will respond to cancer therapies and to reduce the use of ineffective and potentially toxic therapies.

However, achieving the vast potential of personalized medicine will require collaboration between the basic biomedical scientists, clinical trials researchers, epidemiologists, and health outcomes researchers working in the field, and the individuals—surgeons, pathologists, and oncologists, among others—who

ultimately must integrate the scientific advances in everyday practice. For example, biomarkers are increasingly being identified and validated to improve the subtyping and stratification of many cancers, allowing for the development of therapies that target the underlying cause or causes of the cancer. This stratification means better (more personalized) treatment for patients based on specific disease characteristics and genetic profiles. However, the uptake of biomarkers into clinical practice will depend on the capacity of pathology departments to adopt the new knowledge and practices, and the ability of care providers to apply them in the care of their patients. Given that these individuals play a key role in the capacity of health systems to adopt innovations in biomarker development, they have to be a part of research teams to facilitate rapid uptake and to ensure that the research process considers their working environments and the knowledge application and exchange mechanisms of their departments, institutions, and professional groups. Their participation is crucial because the clinical application of new knowledge requires the informed joining of explicit scientific knowledge with local contextual knowledge⁷⁸; otherwise, the risk is that personalized medicine will take the protracted path of other biomedical innovations such as influenza vaccinations, thrombolytic therapies, and fetal occult blood testing. Specifically, it will take decades for important discoveries to reach clinical practice—or to reach a point at which they actually benefit patient care⁷⁹. In Canada, the Canadian Institutes of Health Research personalized medicine initiative⁸⁰ has engaged not only scientists (in areas as diverse as biomedical, clinical, health services and policy, economics, and ethics research) but also clinicians, provincial health authorities, and voluntary health organizations in developing a health research agenda that stimulates discoveries in personalized medicine and integrates the discoveries into clinical practice and health policy.

2.2.2 Innovation Implementation

Narrowing the knowledge–practice gap in cancer care⁴ will also require a better understanding of how innovations are actually applied and integrated into clinical care. Considering the definitions presented earlier, the knowledge produced in the *KT* field is largely multidisciplinary: that is, researchers from various disciplines (psychology, education, medicine, nursing, epidemiology, and management, for instance) are working to find solutions to a common problem. And yet those researchers are working largely from their own discipline-specific perspectives. The resulting separation is observed in the various theoretical frameworks used in *KT* research and practice, which are, for the most part, rooted in specific disciplines⁸¹. However, the multidisciplinary approach has provided just a partial

understanding of the knowledge–practice gap. Advances in understanding will undoubtedly require the integration of discipline-specific theories, concepts, and methods with in-depth knowledge of the realities of clinical practice.

Many innovations implemented in cancer care settings are complex and require both engagement from clinicians and adoption, acceptance, and support (for example, resource support, infrastructure, changes in processes and policies) from organizations and the broader health system. Examples range from the implementation of patient management approaches (multidisciplinary cancer conferences, for instance⁸²) to the use of specific clinical procedures (sentinel lymph node biopsy, among others⁸³) and tools (for example, synoptic reporting⁸⁴). Empirical study of the multilevel (individual, team, organizational, and systemic) factors that influence the implementation, use, and sustainability of such innovations is necessary to successfully change clinical practice and to improve the quality of care in our health system^{10,85–87}. Taplin and colleagues⁸⁸ recently argued that achieving high-quality health care delivery in cancer will necessitate a better understanding of, and thus capacity to influence, the multiple levels of the system within which care is delivered. However, investigating the factors at multiple levels and using the resultant knowledge to optimize interventions and effect practice change will likely require collaborative approaches to research that move beyond multi- and interdisciplinary models. The complexity of the interactions between the various individual, team, organizational, economic, political, and socio-historical components of the health system are unlikely to be fully recognized and understood without integrating concepts and methods from multiple academic disciplines and knowledge from individuals who work within the system.

A transdisciplinary approach to innovation implementation in cancer care means that concepts, theories, and methods from such diverse disciplines as psychology and behavioral sciences, clinical medicine and epidemiology, organizational sciences and management, and systems and complexity theories will have to be integrated at the same time that the knowledge of non-academic stakeholders such as clinicians, patients, managers, executive leadership, funders, sponsors, and others who may be affected by the innovation is included. This inclusive approach will help to ensure that each discipline's most relevant theoretical and methodologic advances are integrated within an overall conceptual framework and that their limitations are addressed by advances in other disciplines²¹.

A focus on methodologic advances in transdisciplinary science initiatives has led to important scientific achievements⁵⁹. Such a focus will also help to ensure that research is sensitive to the realities of everyday practice, including the many factors that

affect how innovations are assimilated into clinical settings. This approach to science is therefore important on conceptual and methodologic levels as well as on a very practical level: By improving the study and understanding of the multiple factors that impede or enable the implementation and use of new tools and practices, interventions that are tailored for specific contexts and that have an increased likelihood of improving the organization, delivery, and outcomes of health care ought to be able to be developed and implemented.

The risks of unidisciplinary innovation in this field are worth a mention. In surgery, for example, new procedures often come into widespread use with minimal evidence to support their safety, efficacy, and cost-effectiveness^{89–92}, likely because of the inherently iterative nature of surgical practice itself and the ongoing adaptation of established procedures to manage complex operative cases⁸⁹. In some instances, innovative techniques and procedures have progressed from use by a small number of surgeons trialing a procedure (and publishing cases series on their findings) to standard practice within a few years⁸⁹. A recent comparison of robotic and laparoscopic hysterectomy for endometrial cancer found that, although robotic surgery represented more than 60% of all minimally-invasive hysterectomies, it offered no clinical benefit over laparoscopic procedures, but was associated with substantially higher costs⁹³. Other research supports those findings^{94,95}. Demonstrating the comparative effectiveness of an innovation such as robotic surgery is therefore necessary before rapid uptake. Comparing the benefits, harms, and costs of new approaches or procedures in real-world settings and investigating the impact of innovations from various societal perspectives (clinicians, patients, funders) requires the integration and use of a variety of research methods and the appropriate interpretation of findings to inform decision-making at both the clinical and the population level. It is unlikely that such research—whether comparative effectiveness research or health technology assessment—can occur within the realm of a single discipline.

2.3 Challenges of Cross-disciplinary Collaboration

Achieving inter- and transdisciplinarity in a productive and rewarding manner is no small accomplishment. Collaborative approaches are often much more labour-intensive than unidisciplinary research²⁷. Building trusting, fruitful relationships across disciplines takes time and effort, and the resulting research endeavors may not reap academic rewards (grant funding, publication) as quickly as does research that takes place within a single discipline. Furthermore, institutional structures within academic settings influence how individuals from various disciplines develop careers, pursue research, and

collaborate with other individuals and professional groups, and probably present significant barriers and disincentives for cross-disciplinary research and practice⁹⁶. Yet some of the barriers may be disappearing as funding agencies advocate for and fund more cross-disciplinary research.

The bringing together of individuals from different disciplines, professions, and institutions means that cross-disciplinary collaboration—particularly transdisciplinary collaboration—will always transect cultural boundaries and ways of knowing, speaking, and doing. Translating research assumptions and philosophies and reaching a point of shared language and understanding will undoubtedly require skillful and inclusive communication. Many researchers may find it difficult to have their assumptions, beliefs, knowledge, and methods challenged by researchers from other disciplines²⁷. In a longitudinal study of transdisciplinary collaboration in the TTURC, Herbert⁹⁷ highlighted the tension and conflict between researchers, particularly between social scientists and biomedical scientists who brought divergent research philosophies, theories, and methods to the projects. More recently, Albert *et al.*⁹⁸ found low levels of receptivity to social scientists among Canadian biomedical scientists, with most of the biomedical respondents asserting that the social sciences cannot produce valid and reliable research results. Such perceptions and judgments likely shape the willingness of the biomedical scientists to engage in interdisciplinary, let alone transdisciplinary, work.

Once a level of shared language and understanding is reached, challenges may continue. Researchers may be inundated by new theoretical and empirical undertakings as they venture outside their areas of expertise and “transform into beginners”⁹⁹. Teams may struggle as they spend considerable time and effort trying to build a research program out of fundamental and largely incompatible assumptions and philosophies⁹⁹. Moreover, working with non-academic stakeholders brings its own challenges, including navigating the professional differences (for example, language, culture) between academic and non-academic environments¹⁰⁰, achieving an understanding of the limitations and realities of each other’s work environments¹⁰¹, and perhaps at the extreme, risking substantial contributions or insights to the larger body of knowledge (scholarly activity) by focusing on solving very practical problems (engineering)⁹⁹.

Given such challenges, how is it possible to plan for cross-disciplinary collaboration and to promote the conditions that lead to optimal collaboration? Recent studies concerning the processes and outcomes of transdisciplinary research teams suggest that the effectiveness of initiatives depends on contextual conditions and collaborative readiness factors⁶⁰. For example, certain institutional, relational, and technical factors appear strongly linked to a team’s likelihood of success. Those factors include

the existence of institutional supports for cross-disciplinary collaboration, the extent to which team members have previously worked together, and the availability of electronic infrastructure to facilitate communication across physical distances^{32,39,102}. In addition, Hebert⁹⁷ noted that the success of transdisciplinarity in the TTURC depended largely on the personal characteristics of the individual researchers: those with a solid scientific base and a willingness to learn about other disciplines and to open their discipline to criticism were more successful in transdisciplinary collaboration. The latter point may be particularly valuable in terms of developing solutions for today's health care problems because conflict and criticism can lead to improved learning and understanding and can act as a catalyst to social-institutional innovation³⁶. Based on the learnings of teams such as the TTURC, a number of resources and toolkits^{103,104} are available to help researchers support and conduct cross-disciplinary collaboration. Those resources assist with issues such as building a cross-disciplinary research team, developing a shared vision, communicating about science, sharing recognition and credit, and managing conflict.

3. CONCLUSIONS

Despite nearly two decades of a growing EBP movement, narrowing the knowledge-practice gap continues to be a slow, complex, and poorly understood process. Nonetheless, Green has argued that the EBP movement has led researchers to recognize they must be responsive to the input and experiences of clinicians and other decision-makers²⁰ and that more practice-based evidence has to be identified, pursued, and used if more EBP is desired¹⁰⁵. Inter- and trans-disciplinarity are approaches to producing evidence that are potentially more relevant and applicable to the everyday realities of clinical practice. As Rosenfield³¹ emphasized two decades ago, research that transcends disciplinary boundaries may be better positioned to lead to long-term improvements in health care practice and policy. The emphasis in cancer research needs to be on developing relationships across scientific disciplines and with clinical partners to optimize the production of innovative research that tackles real-world problems and the translation of findings to real-world clinical care settings.

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5. CONFLICT OF INTEREST DISCLOSURES

The authors have no financial conflicts of interest to declare.

6. REFERENCES

- Grol R. Successes and failures in the implementation of evidence-based guidelines for clinical practice. *Med Care* 2001;39(suppl 2):II46-54.
- McGlynn EA, Asch SM, Adams J, *et al*. The quality of health care delivered to adults in the United States. *N Engl J Med* 2003;348:2635-45.
- Schuster MA, McGlynn EA, Brook RH. How good is the quality of health care in the United States? *Milbank Q* 1998;76:517-63,509.
- Canadian Strategy for Cancer Control (csc). *The Canadian Strategy for Cancer Control: A Cancer Plan for Canada* [discussion paper]. Ottawa, ON: csc Governing Council; 2006.
- Graham ID, Logan J, Harrison MB, *et al*. Lost in knowledge translation: time for a map? *J Contin Educ Health Prof* 2006;26:13-24.
- Davis D. Continuing education, guideline implementation, and the emerging transdisciplinary field of knowledge translation. *J Contin Educ Health Prof* 2006;26:5-12.
- Bero LA, Grilli R, Grimshaw JM, Harvey E, Oxman AD, Thomson MA. Closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. The Cochrane Effective Practice and Organization of Care Review Group. *BMJ* 1998;317:465-8.
- Grimshaw JM, Shirran L, Thomas R, *et al*. Changing provider behaviour: an overview of systematic reviews of interventions. *Med Care* 2001;39(suppl 2):II2-45.
- Grimshaw J, Eccles M, Thomas R, *et al*. Toward evidence-based quality improvement. Evidence (and its limitations) of the effectiveness of guideline dissemination and implementation strategies 1966-1998. *J Gen Intern Med* 2006;21(suppl 2):S14-20.
- Eccles M, Grimshaw J, Walker A, Johnston M, Pitts N. Changing the behavior of healthcare professionals: the use of theory in promoting the uptake of research findings. *J Clin Epidemiol* 2005;58:107-12.
- Improved Clinical Effectiveness through Behavioural Research Group (ICEBERG). Designing theoretically-informed implementation interventions. *Implement Sci* 2006;1:4.
- Stetler CB. Role of the organization in translating research into evidence-based practice. *Outcomes Manag* 2003;7:97-103.
- Flodgren G, Parmelli E, Doumit G, *et al*. Local opinion leaders: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2011;:CD000125.
- O'Brien MA, Rogers S, Jamtvedt G, *et al*. Educational outreach visits: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2007;:CD000409.

15. Shojania KG, Jennings A, Mayhew A, Ramsay CR, Eccles MP, Grimshaw J. The effects of on-screen, point of care computer reminders on processes and outcomes of care. *Cochrane Database Syst Rev* 2009;:CD001096.
16. Canadian Institutes of Health Research (CIHR). About knowledge translation [Web page]. Ottawa, ON: CIHR; 2009. [Available at: <http://www.irsc.gc.ca/e/29418.html>; cited May 28, 2013]
17. Jacobson N, Butterill D, Goering P. Development of a framework for knowledge translation: understanding user context. *J Health Serv Res Policy* 2003;8:94–9.
18. Cornelissen E, Mitton C, Sheps S. Knowledge translation in the discourse of professional practice. *Int J Evid Based Healthc* 2011;9:184–8.
19. Davis D, Evans M, Jadad A, *et al.* The case for knowledge translation: shortening the journey from evidence to effect. *BMJ* 2003;327:33–5.
20. Green LW. Public health asks of systems science: to advance our evidence-based practice, can you help us get more practice-based evidence? *Am J Public Health* 2006;96:406–9.
21. Satterfield JM, Spring B, Brownson RC, *et al.* Toward a transdisciplinary model of evidence-based practice. *Milbank Q* 2009;87:368–90.
22. Haynes RB, Sackett DL, Gray JM, Cook DJ, Guyatt GH. Transferring evidence from research into practice: 1. The role of clinical care research evidence in clinical decisions. *ACP J Club* 1996;125:A14–16.
23. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. *BMJ* 1996;312:71–2.
24. Haynes RB, Devereaux PJ, Guyatt GH. Physicians' and patients' choices in evidence based practice. *BMJ* 2002;324:1350.
25. Guyatt GH, Rennie D, eds. *Users' Guides to the Medical Literature: A Manual for Evidence-Based Clinical Practice*. Columbus, OH: McGraw–Hill Education; 2008.
26. Straus SE, Richardson WS, Glasziou P, Haynes RB. *Evidence-Based Medicine: How to Practice and Teach EBM*. 3rd ed. New York, NY: Elsevier; 2005.
27. Grey M, Connolly CA. "Coming together, keeping together, working together": interdisciplinary to transdisciplinary research and nursing. *Nurs Outlook* 2008;56:102–7.
28. Mitchell PH. What's in a name? Multidisciplinary, interdisciplinary, and transdisciplinary. *J Prof Nurs* 2005;21:332–4.
29. Rose R, Prager D. Views from the field: the value of interdisciplinary research networks. In: *GIH Bulletin*. Washington, DC: Grantmakers in Health; 2009. [Available online at: http://www.gih.org/usr_doc/research_networks_february_2009.pdf; cited May 28, 2013]
30. Zerhouni EA. Translational and clinical science—time for a new vision. *N Engl J Med* 2005;353:1621–3.
31. Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. *Soc Sci Med* 1992;35:1343–57.
32. Stokols D, Fuqua J, Gress J, *et al.* Evaluating transdisciplinary science. *Nicotine Tob Res* 2003;5(suppl 1):S21–39.
33. Turner S. What are disciplines? And how is interdisciplinarity different? In: Weingart P, Stehr N, eds. *Practising Interdisciplinarity*. Toronto, ON: University of Toronto Press; 2000: 46–65.
34. Abrams DB, Leslie F, Mermelstein R, Kobus K, Clayton RR. Transdisciplinary tobacco use research. *Nicotine Tob Res* 2003;5(suppl 1):S5–10.
35. Turkkan JS, Kaufman NJ, Rimer BK. Transdisciplinary tobacco use research centers: a model collaboration between public and private sectors. *Nicotine Tob Res* 2000;2:9–13.
36. Maasen S, Lieven O. Transdisciplinarity: a new mode of governing science? *Sci Public Policy* 2006;33:399–410.
37. Meyer M. Increasing the frame: interdisciplinarity, transdisciplinarity and representativity. *Interdiscip Sci Rev* 2007;32:203–12.
38. Stokols D, Hall KL, Taylor BK, Moser RP. The science of team science: overview of the field and introduction to the supplement. *Am J Prev Med* 2008;35(suppl):S77–89.
39. Stokols D. Toward a science of transdisciplinary action research. *Am J Community Psychol* 2006;38:63–77.
40. Gibbons M, Limoges C, Nowotny H, Schwartzman S, Scott P, Trow M. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London, U.K.: Sage Publications; 1994.
41. Graham ID, Tetroe J. How to translate health research knowledge into effective healthcare action. *Healthc Q* 2007;10:20–2.
42. Jagosh J, Macaulay AC, Pluye P, *et al.* Uncovering the benefits of participatory research: implications of a realist review for health research and practice. *Milbank Q* 2012;90:311–46.
43. Viswanathan M, Ammerman A, Eng E, *et al.* *Community-Based Participatory Research: Assessing the Evidence*. Rockville, MD: Agency for Healthcare Research and Quality; 2004.
44. Tunis SR, Stryer DB, Clancy CM. Practical clinical trials: increasing the value of clinical research for decision making in clinical and health policy. *JAMA* 2003;290:1624–32.
45. Zwarenstein M, Treweek S. What kind of randomized trials do we need? *CMAJ* 2009;180:998–1000.
46. Treweek S, Zwarenstein M. Making trials matter: pragmatic and explanatory trials and the problem of applicability. *Trials* 2009;10:37.
47. Fitzgerald L, Ferlie E, Hawkins C. Innovation in healthcare: how does credible evidence influence professionals? *Health Soc Care Community* 2003;11:219–28.
48. Ferlie E, Wood M, Fitzgerald L. Some limits to evidence-based medicine: a case study from elective orthopaedics. *Qual Health Care* 1999;8:99–107.
49. Glasgow RE, Davidson KW, Dobkin PL, Ockene J, Spring B. Practical behavioral trials to advance evidence-based behavioral medicine. *Ann Behav Med* 2006;31:5–13.
50. Rothwell PM. External validity of randomised controlled trials: "To whom do the results of this trial apply?" *Lancet* 2005;365:82–93.
51. McLeod RS, Wright JG, Solomon MJ, Hu X, Walters BC, Lossing AI. Randomized controlled trials in surgery: issues and problems. *Surgery* 1996;119:483–6.
52. McLeod R. Randomized, controlled trials: is there a role for them in surgery? *Ann Surg* 2006;244:684–5.
53. Canadian Institutes of Health Research (CIHR). Palliative and End-of-Life Care [Web page]. Ottawa, ON: CIHR; 2010. [Available at: <http://www.cihr-irsc.gc.ca/e/36889.html>; cited May 28, 2013]

54. Canadian Institutes of Health Research (CIHR). Access to Quality Cancer Care [Web page]. Ottawa, ON: CIHR; 2007. [Available at: <http://www.cihr-irsc.gc.ca/e/37613.html>]; cited October 16, 2013]
55. Canadian Institutes of Health Research (CIHR). *CIHR Roadmap Signature Initiative in Community-Based Primary Healthcare* [factsheet]. Ottawa, ON: CIHR; 2011. [Available online at: http://www.cihr-irsc.gc.ca/e/documents/fact_sheet_primary_care_e.pdf]; cited May 28, 2013]
56. Canadian Institutes of Health Research (CIHR). About PHSI [Web page]. Ottawa, ON: CIHR; 2008. [Available at: <http://www.cihr-irsc.gc.ca/e/34348.html>]; cited May 28, 2013]
57. United States, National Institutes of Health (NIH), Division of Program Coordination, Planning, and Strategic Initiatives. Common Fund Home > Programs > Common Fund Strategic Planning Report 2009 [Web page]. Bethesda, MD: NIH; 2011. [Available at: <http://commonfund.nih.gov/about-cfspr2009.aspx>]; cited October 16, 2013]
58. Hall KL, Feng AX, Moser RP, Stokols D, Taylor BK. Moving the science of team science forward: collaboration and creativity. *Am J Prev Med* 2008;35(suppl):S243–9.
59. Masse LC, Moser RP, Stokols D, et al. Measuring collaboration and transdisciplinary integration in team science. *Am J Prev Med* 2008;35(suppl):S151–60.
60. Stokols D, Misra S, Moser RP, Hall KL, Taylor BK. The ecology of team science: understanding contextual influences on transdisciplinary collaboration. *Am J Prev Med* 2008;35(suppl):S96–115.
61. World Health Organization (WHO). *Bridging the “Know–Do” Gap. Meeting on Knowledge Translation in Global Health*. Geneva, Switzerland: WHO Document Production Services; 2006.
62. Canadian Cancer Society’s Steering Committee. *Canadian Cancer Statistics 2011*. Toronto, ON: Canadian Cancer Society; 2011.
63. Younis T, Al-Fayea T, Virik K, Morzycki W, Saint-Jacques N. Adjuvant chemotherapy uptake in non-small cell lung cancer. *J Thor Oncol* 2008;3:1272–8.
64. Cree M, Tonita J, Turner D, et al. Comparison of treatment received versus long-standing guidelines for stage III colon and stage II/III rectal cancer patients diagnosed in Alberta, Saskatchewan, and Manitoba in 2004. *Clin Colorectal Cancer* 2009;8:141–5.
65. Winget M, Hossain S, Yasui Y, Scarfe A. Characteristics of patients with stage III colon adenocarcinoma who fail to receive guideline-recommended treatment. *Cancer* 2010;116:4849–56.
66. Kerba M, Miao Q, Zhang–Salomons J, Mackillop W. Defining the need for breast cancer radiotherapy in the general population: a criterion-based benchmarking approach. *Clin Oncol (R Coll Radiol)* 2007;19:481–9.
67. Mackillop WJ, Groome PA, Zhang–Salomons JY, et al. Does a centralized radiotherapy system provide adequate access to care? *J Clin Oncol* 1997;15:1261–71.
68. Paszat LF, Mackillop WJ, Groome PA, Zhang–Salomons J, Schulze K, Holowaty E. Radiotherapy for breast cancer in Ontario: rate variation associated with region, age and income. *Clin Invest Med* 1998;21:125–34.
69. Tyldesley S, Zhang–Salomons J, Groome PA, et al. Association between age and the utilization of radiotherapy in Ontario. *Int J Radiat Oncol Biol Phys* 2000;47:469–80.
70. Zhang–Salomons J, Fourodi F, Huang J, Mackillop WJ. Health system effects on the use of radiotherapy following surgery for breast cancer. *Abstr Acad Health Serv Res Health Policy Meet* 2002;19:45.
71. Ong S, Watters JM, Grunfeld E, O’Rourke K. Predictors of referral for adjuvant therapy for colorectal cancer. *Can J Surg* 2005;48:225–9.
72. Porter GA, Urquhart R, Bu J, Johnson P, Grunfeld E. The impact of audit and feedback on nodal harvest in colorectal cancer. *BMC Cancer* 2011;11:2.
73. Rayson D, Urquhart R, Cox M, Grunfeld E, Porter G. Adherence to clinical practice guidelines for adjuvant chemotherapy for colorectal cancer in a Canadian province: a population-based analysis. *J Oncol Pract* 2012;8:253–9.
74. Urquhart R, Folkes A, Porter G, et al. Population-based longitudinal study of follow-up care for colorectal cancer patients in Nova Scotia. *J Oncol Pract* 2012;8:246–52.
75. Sung NS, Crowley WF Jr, Genel M, et al. Central challenges facing the national clinical research enterprise. *JAMA* 2003;289:1278–87.
76. Westfall JM, Mold J, Fagnan L. Practice-based research—“blue highways” on the NIH roadmap. *JAMA* 2007;297:403–6.
77. Woolf SH. The meaning of translational research and why it matters. *JAMA* 2008;299:211–13.
78. Glasgow RE, Green LW, Taylor MV, Stange KC. An evidence integration triangle for aligning science with policy and practice. *Am J Prev Med* 2012;42:646–54.
79. Balas EA, Boren SA. Managing clinical knowledge for health care improvement. In: van Bommel JH, McCray AT, eds. *Yearbook of Medical Informatics 2000: Patient-Centered Systems*. Stuttgart, Germany: Schattauer; 2000: 65–70.
80. Canadian Institutes of Health Research (CIHR). Personalized Medicine Backgrounder [Web page]. Ottawa, ON: CIHR; 2011. [Available at: <http://www.cihr-irsc.gc.ca/e/43707.html>]; cited May 28, 2013]
81. Estabrooks CA, Thompson DS, Lovely JJ, Hofmeyer A. A guide to knowledge translation theory. *J Contin Educ Health Prof* 2006;26:25–36.
82. Look Hong NJ, Gagliardi AR, Bronskill SE, Paszat LF, Wright FC. Multidisciplinary cancer conferences: exploring obstacles and facilitators to their implementation. *J Oncol Pract* 2010;6:61–8.
83. Wright FC, Gagliardi AR, Fraser N, Quan ML. Adoption of surgical innovations: factors influencing use of sentinel lymph node biopsy for breast cancer. *Surg Innov* 2011;18:379–86.
84. Urquhart R, Sargeant J, Porter GA. Factors related to the implementation and use of an innovation in cancer surgery. *Curr Oncol* 2011;18:271–9.
85. Dobrow MJ, Goel V, Upshur RE. Evidence-based health policy: context and utilisation. *Soc Sci Med* 2004;58:207–17.
86. Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients’ care. *Lancet* 2003;362:1225–30.
87. Grol R, Bosch MC, Hulscher ME, Eccles MP, Wensing M. Planning and studying improvement in patient care: the use of theoretical perspectives. *Milbank Q* 2007;85:93–138.
88. Taplin SH, Anhang Price R, Edwards HM, et al. Introduction: understanding and influencing multilevel factors across

- the cancer care continuum. *J Natl Cancer Inst Monogr* 2012;2012:2–10.
89. Barkun JS, Aronson JK, Feldman LS, *et al.* Evaluation and stages of surgical innovations. *Lancet* 2009;374:1089–96.
 90. Berwick DM. Disseminating innovations in health care. *JAMA* 2003;289:1969–75.
 91. McCulloch P, Altman DG, Campbell WB, *et al.* No surgical innovation without evaluation: the IDEAL recommendations. *Lancet* 2009;374:1105–12.
 92. Wall LL, Brown D. The perils of commercially driven surgical innovation. *Am J Obstet Gynecol* 2010;202:30.e1–4.
 93. Wright JD, Burke WM, Wilde ET, *et al.* Comparative effectiveness of robotic versus laparoscopic hysterectomy for endometrial cancer. *J Clin Oncol* 2012;30:783–91.
 94. Barbash GI, Glied SA. New technology and health care costs—the case of robot-assisted surgery. *N Engl J Med* 2010;363:701–4.
 95. Gaia G, Holloway RW, Santoro L, Ahmad S, Di Silverio E, Spinillo A. Robotic-assisted hysterectomy for endometrial cancer compared with traditional laparoscopic and laparotomy approaches: a systematic review. *Obstet Gynecol* 2010;116:1422–31.
 96. Kahn J. The two (institutional) cultures: a consideration of structural barriers to interdisciplinarity. *Perspect Biol Med* 2011;54:399–408.
 97. Hébert R. What's new in nicotine and tobacco research? *Nicotine Tob Res* 2003;5(suppl 1):S1–4.
 98. Albert M, Laberge S, Hodges BD, Regehr G, Lingard L. Bio-medical scientists' perception of the social sciences in health research. *Soc Sci Med* 2008;66:2520–31.
 99. Giacomini M. Interdisciplinarity in health services research: dreams and nightmares, maladies and remedies. *J Health Serv Res Policy* 2004;9:177–83.
 100. Innvaer S, Vist G, Trommald M, Oxman A. Health policy-makers' perceptions of their use of evidence: a systematic review. *J Health Serv Res Policy* 2002;7:239–44.
 101. Urquhart R, Porter GA, Grunfeld E. Reflections on knowledge brokering within a multidisciplinary research team. *J Contin Educ Health Prof* 2011;31:283–90.
 102. Morgan GD, Kobus K, Gerlach KK, *et al.* Facilitating trans-disciplinary research: the experience of the transdisciplinary tobacco use research centers. *Nicotine Tob Res* 2003;5(suppl 1):S11–19.
 103. Bennett LM, Gadlin H, Levine–Finley S. *Collaboration and Team Science: A Field Guide*. Bethesda, MD: National Institutes of Health; 2010. [Available online at: https://ccrod.cancer.gov/confluence/download/attachments/47284665/TeamScience_FieldGuide.pdf; cited May 28, 2013]
 104. United States, National Institutes of Health (NIH), National Cancer Institute. Team Science Toolkit [Web resource]. Bethesda, MD: NIH; 2013. [Available at: <https://www.teamsciencetoolkit.cancer.gov/public/home.aspx?js=1>; cited May 28, 2013]
 105. Green LW. The prevention research centers as models of practice-based evidence two decades on. *Am J Prev Med* 2007;33(suppl):S6–8.
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