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Research methodology: how to maximize your research potential

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- Scientific education and a clinical background allow orthopaedic surgeons to perform leading research. Several resources, skills and techniques may be developed to maximize their research potential.
- Surgeon-researchers should develop Specific, Measurable, Achievable, Realistic, and Time-defined (SMART) goals. It is critical to define a timeline – which can be 1 year, 3 years, 5 years – to re-evaluate goals and to plan and identify potential obstacles.
- Physician-scientists are a product of training, funding, resources, practice setting, context, environment, and infrastructure. Although orthopaedic surgery has difficulty in recruiting surgeon-scientists, these are essential for the promotion of advances in technologies and treatment, as they have unique abilities to raise questions from the bedside and the operating room.
- The most critical personal traits necessary to succeed as a surgeon-scientist are persistence, resilience, and passion for research. These traits may be innate or acquired through mentorship and from role models.
- Mentors can improve mentees' research efficiency and help them to persevere.
- Clinical researchers and surgeon-scientists should focus their research interests and efforts in their areas of clinical expertise.
- For surgeon-researchers to succeed they must have passion for research, persistence in working toward a goal, collaboration/teamwork skills, resilience, research training/experience, a track record of publications, clear goals and expectations, and a defined research plan as well as being clinically excellent. A formal research degree is desirable.
- Having non-clinician scientists in the team brings added expertise and value.
- Funding and protected research time are important. To provide outstanding clinical care and improve the quality of the care delivered, surgeons must be leaders in innovation and research.

Keywords: SMART goals; surgeon-scientist; orthopaedic research

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Introduction

Scientific education and a clinical background make surgeons exceptionally placed to perform leading research.[1] Today, many surgeons develop novel technology and play an outstanding role in health services and outcomes research, surgical education, ethics research, global surgery research, healthcare administration, and healthcare data research.[2] Surgical research has revolutionized the treatment of many complex diseases.[3]

Orthopaedic surgeons are expected to provide excellent care to patients and to improve the quality of care.[4] Although there are wide variations across Europe and within each country, for many orthopaedic surgeons, career development and promotion is closely associated with productivity in the clinical and research fields. In this article, we outline resources, skills and techniques that may be developed by orthopaedic surgeons to maximize their research potential.

SMART goals

When building a career, every orthopaedic surgeon must find his/her own balance between their personal and professional lives. In each, it is important to identify specific goals to be accomplished, to break these goals into smaller sub-goals, and to follow a time-defined schedule. It is beneficial for surgeon-researchers to identify research goals and develop strategies to accomplish them within a time frame. Goal-setting and goal-management abilities are perhaps as or even more important than funding and external support in order to succeed in clinical practice and research.[5,6] It is also important to identify anticipated distracting circumstances that might disturb one from making progress towards goals.[3] It is critical to define a timeline, which could be, for example, 1 year, 3 years, or 5 years, depending on specific personality and plan.[6,7]

Whenever things do not evolve as planned, it is crucial to re-evaluate goals and to plan and implement changes. Underestimation of task demands, and overestimation of motivation and time left to complete tasks are factors that may interfere with one's ability to succeed.[8]

Clinicians have variable and subjective interpretations of what constitutes a specific or measurable goal.[4] As in other fields, surgeons benefit from learning the skills of creating SMART goals and designing implementation intentions.[5] Generating SMART goals should be part of every surgeon's goal-setting process and involves clarifying what one wants to achieve by developing concrete personal goals that are Specific, Measurable, Achievable, Realistic, and Time-defined (SMART).[6,8] A goal is Specific when it defines the who, what, when and where; Measurable if progress can be tracked and someone can determine if the goal was attained; Achievable if the researcher has the ability and resources to attain it. It is also very important to be Realistic about what one wants to achieve and to set a specific Timeframe.[5] Being the principal investigator on a cohort study and the first author of three manuscripts published in journals with an Impact Factor higher than 1.3 within 3 years may be an example of a SMART goal for an early-career orthopaedic surgeon-scientist.

Personality traits, such as conscientiousness and perfectionism, seem to be relevant to goal accomplishment, while impulsiveness may be distracting. In addition to setting effective goals, it is also important to resist and combat distracting temptations, which may prevent the researcher from attaining his/her own goals.[5] Overload with clinical duties and lack of significant economic compensation for research work are problems that many surgeon-scientists and institutions need to deal with.

Academic measures (presentations, published papers, grant funding, academic rank, clinical studies, chapters, books), clinical measures (practice volume, patient satisfaction, practice niche development), and personal/family measures are the main categories to consider when setting goals.[7]

Physician-scientists

From basic sciences research to health policy development, health systems, and the delivery of health services, the span of clinical and translational science has multiple mainstays.[1] Physician-scientists have been defined as 'physicians who actively participate in patient care, who have undergone additional research training, devote the majority of their time to research, and play an important role in closing the gap between research and clinical practice'.[1,9] A broad range of health professionals conduct health research, usually in highly integrated teams whose approaches span all of the pillars of research. The physician-scientist is a product of training, funding, resources, practice setting, context, environment, and the infrastructure in which he or she is embedded.[9] To succeed as a surgeon-scientist, it is not essential to have a formal education in the form of research-oriented degrees, although this can be helpful in organizing projects and in grant applications.[1]

Physician-scientists are paramount for translation of new knowledge into healthcare delivery and health policy.[9,10] Recognizing that translational health policy, health systems services, and community-based primary healthcare researchers are key drivers of the return on investment to improve the health of people, the Canadian National Consensus Conference made the following recommendations for training and early-career supports for physician-scientists:[9]

1. Establish an independent, national council whose mandate is to provide pan-Canadian oversight of physician-scientist training programs, with a focus on establishing stable, multiyear funding that acknowledges a diversity of training approaches with uniquely defined deliverables.
2. Develop a capacity for funding and mentorship support for physician-scientists.
3. Develop coherent networks of clinician-scientists, including physician-scientists, to reflect the unique cultural and geographic health care issues of Canada and to reflect the interdisciplinarity of health research.
4. Ensure that medical school curricula integrate, as a core curriculum feature, an understanding of the scientific basis of health care, including research methodologies.
5. Ensure that the funding of the physician-scientist trainee is viewed as portable and distinct from the operational funding provided to the training program itself.

In the United States, initiatives including federally funded physician-scientist programmes allow young, motivated scholars to begin rigorous training, which encompasses education and mentorship within both medical and scientific fields, culminating in the conferment of both MD and PhD degrees. The goal is for physician-scientists to be successful in integrating science into their academic medical careers. Although orthopaedic surgery, more than other specialties, has difficulty in recruiting such surgeon-scientists, these are essential in order to promote advances in technologies and treatment, as they have the unique ability to raise questions from the bedside and the operating room, where they receive continuous exposure to unsolved problems.[10]

Training of orthopaedic surgeons should promote the development of skills to perform research work and should allow for dedicated research time. Trainees should also have the opportunity to pursue advanced degrees and to participate in collaborative research.[2] Training programmes ought to include research time and stimulate trainees to learn about research methodology, research ethics, statistics and laboratory work. For non-native English speakers, training in scientific English writing may be needed to succeed.

The modern surgeon should ideally have a solid scientific background, educator skills, and a practice of surgical innovation and advancement.[2] Surgeon investigators must also keep in mind that they need to be competent in scientific methodology and technology, but also maintain their clinical skills and master changing surgical techniques and devices, staying up to date on rapidly evolving technologies and new treatments.[3]

To provide outstanding clinical care, surgeons must be at the forefront of innovating and performing discovery science.[10]

Mentorship and development of surgeon-researchers

Many surgeon-scientists have to overcome bias within their own institutions, as, in some places, the surgeon's role is considered to be primarily to operate, and research in surgical departments is discouraged and not valued.[3] Being rare, role models for the development of a surgeon-researcher career are important.[11] Mentorship is also one of the most valuable aspects of surgeons' and researchers' careers. Mentors can help to find the best way to balance surgical practice and research career, hopefully striving in spite of budget cuts that affect hospitals and academic institutions.[3] Despite not providing ideal conditions for the development of a surgeon-researcher career, many institutions evaluate surgeons based on clinical service, teaching and research.[12]

The surgeon-scientist may have one or more role models and mentors, who usually lead by example and are well recognized in their fields, but also make the effort to contribute to the mentee's development, helping him/her to maximize strengths and overcome problems. Having a mentor who believes in one's potential helps one to persevere.[13,14] Furthermore, mentors can critically review grant applications, research proposals and research work. Their input is crucial for mentees to improve and to become and stay competitive and successful.[3] It is also important for mentors to have mentees and mentor-promising trainees, who may become important collaborators.[13] Medical students and residents may generate research questions, and have different roles in collaborative research, from literature review to data collection, experimental work, data analysis and manuscript writing.

The most critical personal traits necessary for the success of the surgeon-scientist are persistence, resilience, and passion for research. These traits may be innate or acquired through stimulating mentorship in a nurturing environment.[1] It has been shown that the academic success of an orthopaedic surgery department is directly associated with the scholarly productivity and funding of the department's leadership.[15] Development of research potential is also enabled by nurturing environments, where research productivity is valued by the institution, access to advice on research methodology and statistics is available, adequate equipment and human resources exist, internal funding sources are offered and access to external funding is facilitated.

Scientific collaborative conversations can propel major advancements.[16] When promoting the professional development of the surgeon-scientist, cultivating a background of innovation, research, and education is synergistic with developing skills such as public speaking, networking, and writing.[2]

While mentoring processes are important to improve the physician scientist potential, person- and time-specific mentor–mentee meetings are crucial for time-efficient and theme-focussed productivity.[15] Mentors can improve mentees research efficiency by sharing copies of their grant proposals, letters of support, bio-sketches, budgets, and research plans.[17]

Research focus and innovation

Surgeon-scientists have the privilege of providing surgical care to patients combined with the capability to perform innovative research to improve surgical practice. Exposure to sick patients and complex cases on a continuous basis alerts one's mind to the gaps in treatment and opportunities for innovation and progress.[2]

It is advantageous for clinical researchers and surgeon-scientists to focus their research interests and efforts in their areas of clinical expertise.[7,13] Concentrating on a particular area facilitates developing research protocols related to that topic. This yields presentations and publications in that niche area, which will further enhance reputation and leadership.[7]

Kodadek et al. identified 10 personal qualities for surgeon-researchers to succeed: passion for research, persistence in working toward a goal, collaboration/teamwork, resilience, research training/experience, formal research degree(s), track record of publications, clear goals and expectations, defined research plan, clinical excellence (see also Table 1).[11]

To promote the integration of science into orthopaedic practice and thereby improve treatment, institutions need: (1) scientists with an understanding of clinical

Table 1. Necessary tools to succeed as a surgeon-researcher

Institutional tools	Personal tools
Protected research time	Passion and ideas for research
Salary	SMART goals
Mentorship	Teamwork skills
Funding	Defined research plan
Personnel	Research training
Space and infrastructures	Resilience
Support from leadership	Writing skills
Support from colleagues	Clinical excellence

problems; (2) surgeons with an understanding of science; and (3) critical scientific evaluation of the results of clinical practice.[10] There is a wide range of concepts on how research–practice partnerships may be successfully established, so that scientists and clinicians can work together, with different roles, to solve problems and contribute to science.[18] Scientists with an understanding of clinical problems may bring knowledge and skills from different fields such as engineering, informatics, biology, physics, chemistry, etc., and help collaborate with surgeon-scientists to build research that can innovate different fields of orthopaedics, from better understanding the physical forces that drive morphogenesis[19] to better choice of allografts for limb reconstruction.[20]

Institutions must also allow and stimulate the surgeon to think independently, both for the sake of innovation and for the sake of patient care. While standardization, guidelines and pathways play an important role in most current healthcare settings, advances in orthopaedic surgery are dependent on individuals who think outside the box and benefit from openness within the system for their innovations to thrive. In the ideal institution, innovation and standardization occur in harmony, while leaving freedom for the individual researcher to develop ideas, in the best interests of patients.[14]

Teamwork, collaboration and network building

Surgeon scientists have numerous attributes that make them unique. Besides having focus, ambition, and curiosity, which are critical to academic endurance and scientific discovery, surgeons are attracted by challenges and complex and difficult clinical problems and are motivated to improve patient outcomes.[3]

Surgeon investigators deal with problems in a logical and direct fashion. For maintaining relevance and productivity, it is important to approach science as a 'team sport'.[10] Individuality and collectivism are not incompatible and need each other to propel discovery. However, the individual actions of a surgeon-researcher must be questioned and subjected to continuous analysis. Establishing networks is a very useful way of getting critical feedback.[14]

To be competitive, surgeon investigators must tackle sophisticated scientific methods and use a variety of knowledge and skills, ranging from genetics to statistics, while designing their research and applying for funding. However, it is not possible for an investigator to master all techniques and it is imperative to identify and work with strong collaborators, including non-clinician scientists, as part of multidisciplinary investigative teams, who can provide expertise in different areas, thus strengthening the team's efforts.[10] Collaboration, teamwork, networking and negotiation abilities are essential skills for the surgeon-scientist. Given the number of challenges inherent to medical research, it is critical for surgeons to share their experiences.[1] Surgeon investigators must also keep in mind that they need to be competent in scientific methodology and technology, but also maintain their clinical skills and master changing surgical techniques and devices, staying up to date on rapidly evolving technologies and new treatments.[3]

Obstacles to pursuing research

It takes discipline, commitment, and dedication to develop scientific research.[10] Financial stresses and competing clinical demands are some of the factors that may limit the development of surgeon-scientists.[1] The surgeon-scientist must avoid lack of focus, working alone and time-consuming administrative tasks. Surgeon-scientists, particularly in their early formative years, must resist the temptation to enrol in excessive administrative or committee responsibilities that drain their time from valuable academic and research activities.[10]

Another important obstacle to research is the scarcity of funding.[10] Difficulties identified by young surgeon-scientists as to why they face troubles in securing funding include: (1) excessive clinical demands and pressure to generate revenue; (2) a challenging funding environment; (3) insufficient protected time; and (4) excessive administrative duties.[11] Also, as many institutions do not consider research and teaching when evaluating surgeons' productivity, many physicians do not feel encouraged to engage in such activities.[10] Future evaluative metrics must be diverse and appropriate to the type of professional development desired and may include the number of successful collaborations established, the number of publications in quality journals, patents applied for, funding obtained in the form of grants or awards, clinical quality improvement metrics implemented, participation in society committees and leadership, number of students and junior residents as mentees, and educational programmes conceived and implemented.[2]

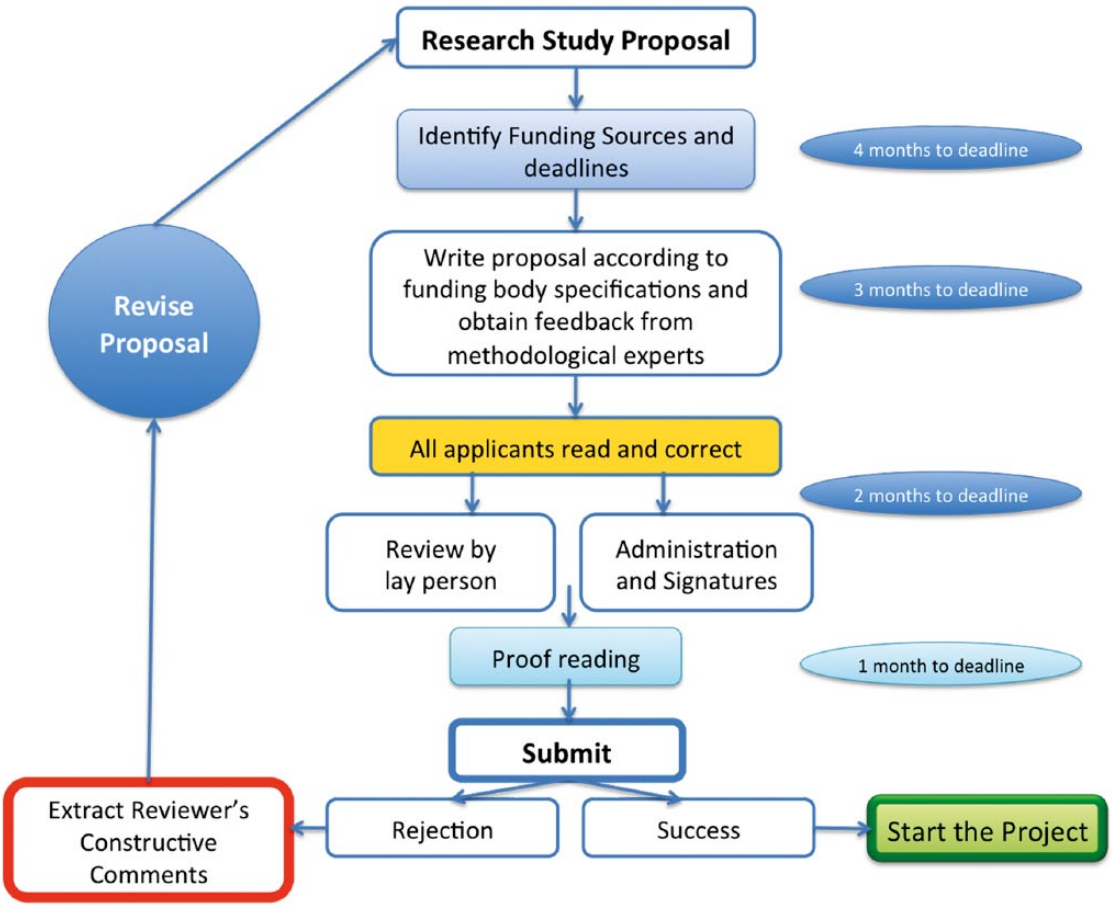

Fig. 1 Flow of an application for funding (adapted from Rankin et al,[4] with permission from The British Editorial Society of Bone & Joint Surgery).

Institutional support

In addition to the time demands of developing research and securing funding, the surgeon-scientist faces the competing time demands of patient care and education.[17] To allow for innovation in surgical therapy, crucial to patients and societies, institutions must provide tools for ensuring the development of surgeon-scientists and their work. The top 10 list of ideal conditions to be fostered includes: protected research time, salary support to offset clinical productivity demands, mentorship (formal)/mentor networks, initial set-up research funds, personnel (technicians, etc.), laboratory space/computing infrastructure, supplies (equipment, computer, etc.), support from the chair, support from the divisional chief, support from division partners (Table 1).[11]

Research funding

Despite being the largest surgical specialty, orthopaedics secures only a small fraction of the available research funds.[4,21,22] A physician-scientist practises clinical medicine and complements this work with high-quality fundable research.[16] In order for a project to succeed in application for funding, it is essential to design a specific, detailed and comprehensive research plan. When pursuing collaborative research, it is important to gather partners and agree on a research plan, proceeding then with budget calculations. During the process of writing the application, partners should ideally meet as often as necessary to ensure agreement on goals and the research programme.[4]

It is said that surgery entails around 95% success, and science entails around 95% failure. Hence, surgeon-scientists must have not only the discipline and patience to propose, revise, and resubmit their ideas for funding but also the tolerance to endure the unpredictable nature of grant funding (Fig. 1).[16] Securing extramural funding derives from potentially high-impact science and surgeon perseverance in proposal submissions.[1,10]

Although applications for grants and funding are time and resource consuming, the in-depth background reading required to write an application or write a scientific manuscript promotes skills in analysis and critical

appraisal, important in making evidence-based decisions for patient care.[2]

Collaboration with industry partners and academic centres may open wider possibilities to secure funding for research projects. In 2008, the UK NHS started 'Collaborations for Leadership in Applied Health Research and Care' (CLAHRCs) between university health research centres and NHS service-providing organizations and local communities. The aim is to 'stimulate innovation and best practice across local health communities using two-way collaborative learning and delivery pathways' in order to link researchers and policymakers, managers, front-line clinical professionals, patients and community representatives.[21] These partnerships also facilitate knowledge translation, which is a priority for most funding entities.[23]

At present, Horizon 2020 is an important opportunity for orthopaedic researchers in Europe, as it may allow local research projects to grow into larger programmes through collaborations funded via the European Union.[4] The European Federation of National Associations of Orthopaedics and Traumatology (EFORT) Foundation also funds some projects and can be approached directly with outline proposals.[4] Funding may also come from industry grants, foundations and private donors. In some settings, intramural funding (philanthropy, endowments, etc.) can be accessed and may provide support to develop surgeon-scientists' projects.[1]

Science takes time and funding, while funding takes time. When pursuing funding, a surgeon-scientist must have a combination of confidence, perseverance, and a mind-set not dissuaded by rejection.[17]

Research questions and study design

The development of a research question, aim and objective is an interactive and inductive process that takes place over time, entailing consultations with mentors and colleagues and researchers, knowledge of the published literature, and use of the appropriate criteria.[24] The success of a study relies on asking a Feasible, Interesting, Novel, Ethical and Relevant research question.[25] For creating quantitative research questions, Richardson suggested the PICO format. When phrasing the question, the researcher should mention Population, Intervention, Comparison and Outcome.[26] For questions in qualitative research, Kahn proposed the PEO format, so that the research question should mention Population, Exposure and Outcome.[27] The question must be grounded in research, coherent, clear and ask precisely what the researcher wants to find out. This allows for planning and identifying the necessary methodology, sample size, data collection and data analysis.[25]

Epidemiology and biostatistics are essential tools of clinical research. An understanding of study design, hypothesis testing, diagnostic performance, measures of effect, outcomes assessment, evidence-based medicine, and biostatistics is essential both for investigators conducting clinical research and practitioners interpreting clinical research reports. In observational studies, researchers observe patient groups without allocation of the intervention, whereas in experimental studies researchers allocate the treatment.

Experimental studies involving humans are called trials. Research studies may be retrospective, meaning that the direction of inquiry is backward from the cases and that the events of interest transpired before the onset of the study. Alternatively, studies may be prospective, meaning that the direction of inquiry is forward and that the events of interest transpire after the onset of the study. Cross-sectional studies are used to survey one point in time. Longitudinal studies follow the same patients over multiple points in time.[28] The gold standard for clinical trials is the prospective randomized controlled trial which produces the highest accuracy in data collection and is the final test of a new therapy.

Future research

Breakthrough advances in medicine result mainly from the translation of new basic scientific knowledge into clinical practice, rather than from assessment, modification or refinement of current methods of diagnosis and treatment.[10] Motivated surgeon-scientists are critical to progress[3] within research areas of great interest in orthopaedics, such as:

- Molecular/genetic aspects of orthopaedic diseases
- Stem cell research
- Growth plate research
- Nanotechnology
- Treatment of trauma
- Biologic therapies
- Tissue engineering
- Bio-engineering research

The surgeon-scientist has a unique perspective as one who understands clinical needs, identifies areas for research, and translates discoveries from bench to bedside.[17] In order to provide outstanding clinical care, orthopaedic surgeons must be leaders in research and innovation.

Conclusions

Surgeon-scientists develop a set of skills that sets them apart from non-surgeon investigators and non-investigator surgeons. The surgeon-scientist needs discipline and humility in seeking scientific direction and mentorship, institutional support, and ultimately funding.[17]

Surgeons perform important and impactful work in novel technology development, health services and outcomes research, surgical education, ethics research, global surgery research, healthcare administration, and healthcare data science research.[2] To survive and thrive in a highly competitive and evolving clinical and research environment, a surgeon-researcher must find collaborators who complement and synergize his/her strengths. Working within a group and sharing ideas and discoveries can be highly rewarding and intellectually stimulating.[10,17]

Crucial components have been identified to facilitate a successful research career: personal desire and drive for investigation, focus on a research theme, guidance/mentoring (person- and time-specific), continuous personal mentor–mentee relationships, dedicated time, research writing (articles and grants), funding, support of the department chair, protected research time and lab or office space.

Research and patient care demand much dedication for the surgeon-scientist to remain up to date in both fields. While all surgeons deal with a schedule of patients, the surgeon-scientist additionally deals with research time and challenges.[17] To provide outstanding clinical care and improve the quality of the care delivered, surgeons must be leaders in innovation and research.

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