A review of individual and institutional publication productivity in medical radiation science

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INTRODUCTION

Evidence-based practice has become the cornerstone for all health professionals, and refers to the application of the best available research outcomes in clinical decision-making [1]. Like all others, the Medical Radiation Science (MRS) professions of Radiation Therapy, Diagnostic Radiography and Nuclear Medicine must continue to develop their evidence-base for practice. This requires quality information to tailor service delivery and patient care. MRS have experienced tremendous technological change and that has driven advancement in the area of professional development, including extension in every aspect of the role from image acquisition to image interpretation [2, 3]. MRS can be variously seen as an established profession in certain parts of the world and an emerging one in others. Technological advances in MRS are further driving the need for role extension and specialization [4]. It continues to be crucial that beyond information and teaching on the technical aspects, role extension is matched with adequate research to support our practice and emerging professionalism [5]. Effective dissemination of such research findings in peer-reviewed journal publications, textbooks, and conference presentations [1] is critical to development of optimal standards for tailoring patient-centered practice.

Professional development and the need for evidence in clinical decision-making is driving research by MRS professionals, both clinical and academic. Increasingly, there is pressure on academics to "publish or perish"[6], as metrics such as publication count, citation rates, and impact factor are used as key performance indicators (KPIs) for obtaining funding and career progression [7]. Likewise, these metrics are also required by funding bodies as evidence of impact [8]. In parallel with this, there is increased interest in international research collaboration among researchers and institutions to enhance the quantity and quality of research output. Such

collaborations also enable information sharing, timely completion, and dissemination of research findings [9]. The internationally accepted method for generating high quality evidence is through the process of exposing work to scrutiny by other scientists and ultimately publishing in peer-reviewed journals. The quality of a publication is then judged by bibliometrics [10]. "Bibliometrics is statistical analysis of written publications, such as books or articles" [11]. It measures the impact of the publication and has many metrics to quantify such impact [10, 12]. Bibliometrics also allow for evaluation of author, institutional, and professional productivity as well as the degree of collaboration [13]. Higher bibliometrics are beneficial for institutional or professional accreditation, and international ranking [7]. Through improvements in bibliometrics, an institution may improve their success rates in grant applications and attracting philanthropy. Furthermore, they are used by academic institutions as scientific gauge for purposes such as employment and salary decisions, performance reviews, promotion, and allocation of research resources [14].

The bibliometric parameters used for the evaluation of the relevance of a publication include journal impact factor (JIF), citation analysis, SCImago journal rank (SJR) and many more. Each of these metrics has its specific attribute that makes is relevant to publication analysis, however, impact factor and citation analysis are the most common metrics used in many bibliometric studies [10, 12]. JIF refers to the average number of citations to recently (within 2 years) published articles [15]. Citation analysis is a measure of the fequency of cititation and can also use h-index (the number of papers (*h*) that have at least *h* citations each) and i-10 (number of articles (i) with at least 10 citations) to gauge the productivity of publications [13, 16]. SJR is developed from the information contained in the Scopus® database. It assesses the influence of journals including those that do not have an impact factor in Web of Science™ [17]. "The

SJR indicator attributes different weight to citations depending on the "prestige" of the citing journal without the influence of journal self-citations; prestige is estimated with the application of the PageRank algorithm in the network of journals" [17].

Impact factor and citation analysis are a form of endorsement, providing an indication of the relevance of a publication to a particular field relative to other publications. An internationally agreed system of judging the merit of publications has been established. Thompson-Reuters produce journal citation reports (JCR®) and JIF that are recognized by all publishers. Thompson-Reuters Web of Science™ listing is through an application process. Journals not listed either have not applied or may have been unsuccessful. Currently, no MRS Journal is indexed in Web of Science™.

Studies have evaluated MRS authors' productivity [18, 19], however, these studies restricted their evaluation to MRS journals only such as *Radiography* (Society and College of Radiographers, Elsevier), *Journal of Medical Imaging and Radiation Sciences (JMIRS)* (Canadian Association of Medical Radiation Technology, Elsevier), *Journal of Medical Radiation Science (JMRS)*, previously called the "The Radiographer" (AIR, Wiley), *The South African Radiographer* (Society of Radiographers of South Africa*), Radiologic Technology* (American Society of Radiologic Technologists), *Radiation Therapist Journal* (American Society of Radiologic Technologists) and *The Journal of Nuclear Medicine Technology (JNMT)* (Society of Nuclear Medicine and Molecular Imaging). These journals, albeit peer-reviewed have no impact factor and low bibliometrics in comparison to journals in similar fields such as Radiology. Four MRS journals are indexed on SJR, and according to SJR metrics, *Radiography* has a two-year citation per document average of 0.8, *JMIRS* has 0.48, *Radiologic Technology* has 0.44, *JNMT* has 1.09 compared to 4.17 for the *European Radiology* and 6.6 for *Radiology*.

Therefore, many MRS authors chose to publish in journals with higher impact factor [18]. To fully understand MRS research impact, an all-inclusive analysis is required and should take publications in all peer-reviewed journals into consideration. Therefore, this study aims to investigate the research impact of active MRS researchers and examines the research output of institutions globally.

MATERIALS AND METHODS

To identify productive MRS authors we used an iterative search strategy that first identified productive authors using the literature and database searches, and then examined their productivity using a systematic search of "SciVal®" (Elsevier). SciVal® is a database with a set of meshed independent modules. It comprises of three independent units: *overview*, which provides a layout of the research performance of the organization according to parameters such as outcomes, collaboration and impact in a field; *benchmarking*, which compares organizations based on their achievement metrics, highlighting the weaknesses and strengths of such establishments; *collaboration analysis*, which identifies and scrutinizes ongoing, probable, and suitable collaboration opportunities. SciVal® also enables comparative analysis of a researcher's or an institution's impact relative to other researchers or institutions in a given field in terms of number of publications and citation metrics [20].

Identification of authors and impact

Two previous publications [18, 19] have identified and listed the most productive MRS authors using various methodologies. This published evidence on productivity provided 52 names. MRS co-authors of those named in these two papers [18, 19] were then added to the list, and their

colleagues were identified through departmental websites, ResearchGate (RG), and Google Scholar. These sources were also used to identify the professional alignment of the authors. Authors were excluded if they do not identify themselves as diagnostic radiographers, nuclear medicine technologists, radiation therapists or academics in these areas. Many dual-qualified MRS professionals were identified. Those currently identifying themselves as medical physicists, radiologists, medical statisticians orprofessions other than MRS were excluded.

The SciVal® search was carried out for all authors on the same day to avoid any bias. The identification of active authors was based on number of publications and citation counts over a five-year period (1st of Jan 2010 – 31st December 2014). In the current study an "active author" is defined as one that has published at least two SciVal® indexed articles in peer-reviewed journals within the period of review. Conference papers, book chapters, editorials, letters to editors, and professional columns were excluded. For each of the authors, the total number of publications in peer-reviewed journals (P), total number of citations (C), international collaboration metrics (IC), number of citations per publication (CPP), h-index, and i-10 were extracted from SciVal® (Table1). As it has been demostrated that individuals listed as first, second, and last authors make the highest intellectual contribution to a published work [21-27] the current work assessed whether authors were leading the research or co-authoring by judging their position in the list of authors for each paper. Authors listed as first, second or last (FSL) were classified as lead researchers and those listed in-between as co-authors. Each author's total impact was then quantified by:

$$\text{Total Impact} = P \times C \times FSL$$

Identification of authors in turn enabled identification of the most active MRS research institutions in order to provide an indication of where MRS outputs originate from. The MRS research portfolio of these leading institutions was assessed by evaluating the citation count, number of citing countries, and journal count of that institution. The benchmarking module of SciVal® was used to compare between institutions for the impact of their publications. Finally, the ranking of institutions involved in MRS research was assessed relative to their 2014 – 2015 Times Higher Education World University Rankings.

RESULTS

A total of 112 authors were identified initially, of which 7 were judged as not active having no peer reviewed work indexed in SciVal® during the period of review. The remaining 105 were considered active having published at least two SciVal® indexed peer reviewed article during the period. The active authors came from 50 institutions worldwide. The majority of the authors were from the UK [24.6% (n = 27)], Australia [21.8% (n = 24)], Canada [20% (n = 22)], and the USA [13.5% (n = 15)]. The number of peer-reviewed publications for authors ranged from 1 to 90 (n = 1,263). Of the active authors identified, 9.5% (n = 10) had published 30 or more articles, 31.4% (n = 33) had published between 10 and 29, 32.4% (n = 34) had published between 5 and 10, and 26.7% (n = 28) had published between 2- 4articles. A list of the 30 highesr impact authors within the period is presented in table 1. Authors are arranged in a descending order based on their total impact. The order of authors' productivity clearly changes based on the metric used to quantify productivity.

Table 1: List of the 30 highest impact MRS authors within the period reviewed

The total citation count of all authors identified was 3,472 (range 0 – 224). The h-index and i-10 of MRS researchers ranged from 0 – 34 (mean = 5.6) and 0 – 34 (mean 2.48) respectively. The h-index and i-10 of the 30 highest impact authors are shown in table 1. There was a wide variability in the level of international collaboration amongst authors. For authors with multiple publications, international collaboration was highest for Irish authors followed by Australian and UK authors (Table 1).

The scholarly output of the top 10 institutions involved in MRS research during the period of review is presented in figure 1. These are universities with at least two authors that had published a total of five SciVal® indexed articles in the last five years. The University of Toronto, Canada leads the MRS scholarly output chart, but it was overtaken by the University of Sydney, AU in 2013. These two were followed by the University of Salford, UK, and The Hong Kong Polytechnic University, Hong Kong. Overall, within the period under review the number of publications in peer-reviewed journals (P) of the top five universities involved in MRS research were: University of Toronto (n = 144); University of Sydney (n = 122); University of Salford (n = 70); Hong Kong Polytechnic University (n = 55); University College Dublin (n = 51).

Figure 1: Scholarly output per year of institutions leading MRS research. This is based on the total number of Scival® indexed papers per year for all identified authors in that institutions.

The citation count and international reach (as judged by the number of citing countries) of the top 10 universities involved in MRS research is shown in figure 2. The University of Toronto's

publications were cited in the highest number of countries (n = 60) followed by the University of Sydney (n = 53) and University College Dublin (n = 44). The University of Sydney led the journal count (n = 58) followed by Hong Kong Polytechnic University (n = 35) and Curtin University (n = 29). Of the Universities involved in MRS research, only two were listed in the top 100 of the 2014 – 2015 Times Higher Education World University Rankings. These are the University of Toronto, ranked 20th, and University of Sydney, 60th.

Figure 2: MRS research portfolio of institutions leading in MRS research. The size of the circle represents the journal count with larger circles representing wider spread of journals in which that institution published.

DISCUSSION

The current work demonstrates that the most active and productive MRS researchers are in the UK, Australia, Canada, and the United States. A majority (73.3%) of the active authors had published at least five articles in peer-reviewed international journals within the period under review. The work also reports for the first time the range of citation counts and the citations per publication for MRS research. The most cited MRS researchers are from Universities in Canada and Australia. International collaborations were particularly noted among Irish and Australian authors. The data produced also demonstrates a fluctuating pattern in the scholarly output of the institutions leading MRS research, with the University of Toronto, University of Sydney, and University of Salford demonstrating the highest research output within the period of review (Figure 1). Similarly, the MRS research portfolio based on the number of citing countries and

citation count is highest in the University of Toronto, and University of Sydney; however, the University of Sydney's research output was more widely spread in terms of journal count (Figure 2).

Evaluation of MRS research productivity is becoming increasingly relevant due to the current drive towards evidence-based practice in patient-centered care. Identification of the most active researchers in the field also helps potential research candidates in decision-making regarding institutions and supervisors for their research degrees such as Ph.D. Many metrics have been used to quantify authors' productivity in bibliometric studies, and include publication count and citation analysis, including the h-index and i-10 analyses [10, 19, 28, 29]. The current study employed a range of metrics to report author impact, and has demonstrated that changes in the metrics used give a different impression of the reported productivity. Publication count (P) tends to improve the reported productivity of authors who have published many papers, regardless of their quality or the number of times they have been cited. Therefore, using publication count alone gives little indication of the impact of their work.

Metrics such as number of citations (C), citations per publication (CPP), h-index and i-10 are significant in assessing authors' impact, as they show that authors' work is not just read but cited, thus deemed to have made significant contribution to academic discussion and ultimately the evidence base [13, 16]. The h-index, in particular has been used in bibliometric studies to quantify author's research impact [19, 28, 29]. A wide variation was observed in h-index of MRS researchers (range= 0 – 34), and the mean h-index was 5.6 for the MRS profession. Much higher mean h-indices has been reported for seven other disciplines, ranging from 19.9 – 95.9. In one study comparing many academic disciplines computer science was reported to have the lowest mean h-index (19.9) and clinical medicine had the highest (95.9)[30]. Although the h-index

measures author's performance based on productivity and citation count, it does not take into consideration authors' contribution to an article and self-citation [27, 31, 32]. The h-index also improves for researchers who have been publishing over longer periods as the number of citations for their publications increases over time. However, as some authors listed in such a publication may have made minimal contribution to the work, their h-index and i-10 may be boosted by other coauthors [24, 26]. An example of this is evident in the current study where one author with 16 peer-reviewed publications and listed first, second or last in only four of these, has the highest i-10 of 34 and second highest h-index of 22.

The increasing pressure to "publish or perish", may have led to the listing of authors with little contribution to a publication, a phenomenon known as "honorary", "loose" or "gift" authorships [33, 34]. Gift authorship is contentious in the literature with many arguing that not all contributions to the work deserve credit in the form of authorship [21, 22, 33-35]. The contribution of an author influences his/her position in the author list, and the first and last authors are generally believed to have made the highest contributions, followed by the author listed second [21-27], with a wide variation reported in the contribution of subsequent authors. Therefore, combining total number of publication (P) with the position of the author and citation count (CFSL) seems intuitive to give measure of the total impact of the author. Using this criterion, we ranked the 105 authors and the 30 with the highest impact are shown in table 1.

The top 10 universities involved in MRS research are shown in figure 1. A higher scholarly output was observed for the University of Toronto, Canada. Most of the authors from this institution seem to have a clinical-academic link and be affiliated with either the Princess Margaret Cancer center or the Department of Radiation Therapy Odette. This may be due to the existence of dual clinical/academic appointments and perhaps, their higher scholarly output is

due to being able to access more clinical data and/or factors driving their research agenda. Clinical-academic positions are crucial, as MRS professionals require clinical training, mentorship, and research and management skills in order to attain the desired level of clinical expertise [36]. As MRS is constantly evolving, continuous professional development is relevant to ensure that professionals are updated about the evidence-base in the field. Thus, expanding the number of these positions is an important strategic issue for MRS. It should also be noted, and is particularly relevant to career planning, that the majority of the most productive authors are academics, frequently acting as research supervisors for PhD and Masters students. They also commonly mentor early career researchers. Therefore, these highly productive individuals contribute not only to the evidence-base, but a crucial part of their role is to develop the next generation of emerging researchers.

Another interesting observation is that MRS authors in Canada and the UK tend to publish mostly in journals domiciled in their countries and in a small number of journals. However, MRS research output from the University of Sydney has the widest spread of journals (Figure 2), suggesting a good level of contribution to other related fields. These are mainly radiology journals such as Academic Radiology, Clinical Radiology, American Journal of Roentgenology, British Journal of Radiology, and Radiology, but also include trans-disciplinary publication in European Journal of Cancer, Journal of Allied health, and Journal of Obstetrics and Gynecology. Thus, although these are not core MRS journals, the evidence published in such journals should be relevant for tailoring role extension for MRS professionals or extending the MRS knowledge base of another field. Where authors are providing evidence to other fields then it can be argued that impact into MRS is either reduced, or it's relevance to other disciplines enhanced.

Collaboration is an effective way of sharing research ideas and providing solutions to difficult research questions. A previous study had reported difficulty in assessing the level of collaboration between academic and clinical researchers [37]. The current work focused on international collaboration and demonstrates a good level of such collaboration among Irish and Australian MRS researchers, but less among authors from other countries. This may be due to emigration, as the two lead authors in the University of Sydney have collaborated with authors in their former institution (University College Dublin). As projects complete however, these international collaborations could decrease. Overall, the findings demonstrate a low level of research activity among MRS professionals within the period of review. Research inactivity by the 30 highest impact authors listed in table 1 could have a catastrophic impact on the number of radiography-related articles published globally. The best possible effort was made to identify and include all MRS professionals to the current review. However, it is possible that some key individuals may have been missed. In this paper it would be impossible to create a completely comprehensive list of MRS researchers for the entire world, and future research should develop a better mechanism to achieve this. We propose a web-based system where MRS authors can identify themselves in order for future studies to obtain a more comprehensive list.

The data raises some worrying concerns. Low publication rates and citations counts and h-indices raise questions about the viability and sustainability of the MRS evidence base going forward. This indicates that perhaps there is a need for mentoring by experienced MRS researchers for the rest of the MRS research community. There are also no developing countries represented in the top 30, however, there are some in the list of 105 active MRS researchers. The reasons for the low level of activity among MRS professionals in the developing world is

unclear, but a lack of motivational factors with employment structure, limited training in research [38], a lack of funding and research facilities have been implicated [39].

Previous studies have identified up to 2,083 unique authors of MRS research published in MRS journals from 2004–2013 [18, 19, 37, 40]. The strategy of the current paper was to identify active MRS researchers only and was based on research activity in the period of review. A limitation of the current study is that self-citation was included in the citation analysis; this was done to show the cumulative nature of MRS authors' research [41]. The strengths of the current evaluation include that it is not restricted to publications in MRS journal. Also, a wider range of bibliometrics was employed in the evaluation of MRS research productivity. The data produced also captured for the first time the research impact of active MRS researchers and institutions worldwide.

The findings demonstrate a low level of research activity among MRS professionals within the period of review, with the most active and leading MRS researchers and institutions domiciled in the developed world. The level of international collaboration amongst MRS professionals is gradually evolving; however, more effort is required to inspire a research culture in MRS professionals. Such culture as well as wider and sustainable international collaboration amongst MRS personnel may hold the key to establishment of evidence-based MRS practice. Also using tools like SciVal individual researchers and research teams can identify areas of strength and risk and take corrective actions as needed.

CONCLUSION

For the first time the world leading MRS research units have been identified, and previous published works have been built upon to provide a larger list of research active MRS

professionals. Data produced raise some worrying concerns. Low publication rates and citations counts and h-indices raise questions about the viability and sustainability of the MRS evidence base going forward.

Name	Institution	Cntry	P	C	CPP	IC	h-index	i10	FSL	CFSL	Total Impact
Brennan, P	University of Sydney	AU	90	208	2.3	54.4	14	2	70	1456	1310400
Hogg, P	University of Salford	UK	57	105	1.8	19.3	8	6	51	5355	305235
McEntee, M	University of Sydney	AU	54	159	2.9	74	8	5	33	5247	283338
Halkett, G	Curtin University	AU	34	214	6.3	2.9	12	1	28	5992	203728
Holden, L	University of Toronto	CAN	66	224	3.4	12.1	15	18	10	2240	147840
Currie, G	Charles Sturt University	AU	41	78	1.9	48.8	8	4	33	2574	105534
Mitera, G	University of Toronto	CAN	31	175	5.6	6.4	8	7	18	3150	97650
Wu, W	The Hong Kong Polytechnic University	HK	30	116	3	33	8	3	28	3248	97440
Ying, M	The Hong Kong Polytechnic University	HK	32	102	3.2	12.5	24	3	22	2244	71808
Rainford, L	University College Dublin	IRE	31	82	2.6	80.7	8	4	26	2132	66092
Munn, Z	University of Adelaide	AU	25	71	2.8	20	4	2	21	1491	37275
Ryan, J	University College Dublin	IRE	26	116	4.5	61.5	6	5	10	1160	30160
Rosewall, T	University of Toronto	CAN	19	105	5.5	21	12	16	14	1470	27930
Reed, W	University of Sydney	AU	28	74	2.6	42.9	5	1	13	962	26936
Jon, F	University of Toronto	CAN	27	106	3.9	0	7	3	6	636	17172
Wheat G	Charles Sturt University	AU	21	69	3.3	52.4	8	7	11	759	15939
D'Alimonte, L	University of Toronto	CAN	19	40	2.1	15.8	3	1	15	600	11400
England, A	University of Salford	UK	17	38	2.2	17.6	7	1	17	646	10982
Davidson, R	Royal Melbourne Institute of Technology	AU	14	97	6.9	57.1	7	3	8	776	10864
McNulty, J	University College Dublin	IRE	13	61	4.7	69.2	4	2	10	610	7930
Cox, J	University of Sydney	AU	15	47	3.1	6.7	6	0	10	470	7050
Kowalczyk, N	Ohio State University	USA	14	42	2.3	21.4	3	1	11	462	6468
Owen, R	Queensland Health	AU	15	81	5.4	0	7	5	5	405	6075
Middleton, M	Radiation Oncology Queensland	AU	14	37	2.6	21.4	2	2	11	407	5698
Folks, R	Emory University	USA	16	83	5.2	18.8	22	34	4	332	5312

Snaith, B	Mid Yorkshire/ Pinderfields Hospital	UK	15	22	1.5	0	5	4	15	330	4950
Hardy, M	University of Bradford	UK	13	25	1.9	0	8	3	13	325	4225
Di Prospero L	University of Toronto	CAN	18	16	0.6	3.8	4	0	14	224	4032
Toomey, R	University College Dublin	IRE	12	42	3.5	33	4	2	7	294	3528
Zarb F	University of Malta	MAL	10	29	2.9	80	3	1	10	290	2900

Cntry: country; TNP: total number of publications; TNC: total number of citations; CPP: citation per publication; IC: international collaboration; FSL: 1st, 2nd and last author; CFSL: No. of citations for 1st, 2nd and last author; PCFSL: No. of Pubs x No of citations x 1st, 2nd and last author

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