Making Waves: The Impact of the Georgia CTSA Publication Portfolio from 2007-2021

Big Splashes and Ripple Effects on Translation

2021 Internal Report

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Executive Summary

Background

The Evaluation & Continuous Improvement program periodically evaluates the growing publication portfolio that has resulted from research supported by the Georgia Clinical and Translational Science Alliance (Georgia CTSA). We last assessed the full portfolio in 2016, finding a robust, diverse, and highly impactful portfolio compared to other CTSA hubs. In this update, we evaluate progress made in publication and citation activity from 2007 through 2021, including the transition from the Atlanta Clinical and Translational Science Institute (ACTSI) to the Georgia CTSA, with the addition of a novel kind of publication analysis- **altmetrics**. Traditionally, publication analyses have examined productivity and influence through academic citations. Altmetrics, on the other hand, describe the influence of published research in non-academic spheres, such as media and community discourse, technological patents, and public health policy. Taken together, academic citations and altmetric citations can illustrate how publications are ‘making waves’ that can accelerate translation. Papers with early

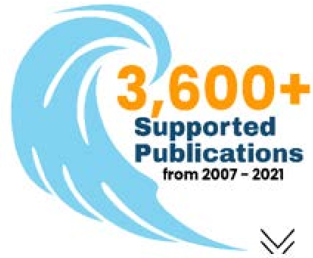
altmetric attention can be thought of as ***big splashes*** with immediate impact, whereas papers with high rates of academic citation reflect ***ripple effects*** of accumulated influence over time.

This report also contributes a novel evaluation of bibliometric science itself. Previous research in numerous fields has found small to null associations between altmetrics scores and citation counts. However, no previous research has examined this relationship in clinical/ translational research, nor the relationship between altmetrics and innovative citation impact factors like the NIH’s Relative Citation Ratio (RCR). It is also unclear whether any relationship between altmetric attention and citation is due to publication in journals with higher journal impact factors (JIFs), which, by definition, are more likely to be read and cited. In this study, we evaluate the Georgia CTSA’s advancement in publication and citation activity, with new altmetric indicators of translational impact.

Method

For all publications that acknowledged support from any Georgia CTSA grant (2007-2021), we collected citation and translational feature metrics, author affiliation, JIF, and Altmetric Attention Scores (AAS), which track public/community attention in sources such as news stories, tweets, blogs, patents, and policy documents. We described the portfolio in terms of publication output by year, multi-institutional affiliation, and translational features. We then assessed the influence of the portfolio in terms of academic and altmetric citation trends over time. Finally, we used correlation analysis to examine the relationships among journal impact, altmetrics, and citation impact in this portfolio over time.

Results



We identified **3,681 articles** that were supported by the Georgia CTSA from its inception in 2007 through mid-2021. Most research involved human subjects, and frequent research areas included infectious disease, epidemiology, cardiovascular disease, psychiatry, and pediatrics. A total of **2,649** articles were multi-institutional, including 232 that were co-authored across Georgia CTSA institutions and 734 that were co-authored with researchers across the national CTSA consortium of hubs. Both the publication output and the proportion that were multi-institutional increased over the past funding cycle.

Thus far, these articles have been **cited almost 150K** times, for a mean RCR citation impact score of 2.5, meaning that these articles have, on average, been **cited 2.5 times as often** as comparable articles from the same year and field. The publications have been referenced **65K+** times in documented altmetric sources with the number of mentions increasing over time. The mean AAS of **25** included **5,800+** news stories references, **53K+** Twitter references**, 900+** blog references, **269** Wikipedia references, **1,333** patent references, and **476** policy document references. Among a subset of publications with complete data, correlation analysis showed that AAS, JIF, and RCR were all positively and significantly associated with one another.

Conclusions

This evaluation reveals the considerable advancement in published research supported by the Georgia CTSA since the inception of the program, and especially since the last grant renewal. Cutting-edge bibliometric tools provide a new angle on the diverse ways that Georgia CTSA-supported research is being used across both academic and non-academic circles. Results show that both publication and citation rates are accelerating, and that multi-institutional research has been on the rise since the expansion of the ACTSI to the Georgia CTSA. Supported publications are making waves, from big splashes in early public and community attention to ripple effects on academic use over time. Moreover, big splash articles with more altmetric attention have ripple effects through increased citation influence. We view this as evidence for a chain of events wherein clinical and translational science is supported by the Georgia CTSA, and that research is published in academic journals, some that are very high impact. Those publications are then discussed and referenced in non-academic and community forums, and the more that happens the more likely they are to be used and cited in subsequent research. We believe that this opens the door to moving medical science forward toward usable technological and translational advancement.

Background

The Georgia Clinical & Translational Science Alliance (Georgia CTSA) was established in 2007 by the National Center for Advancing Translational Science (NCATS) of the National Institutes for Health (NIH) to accelerate clinical and translational education, research, and community engagement to impact health in Georgia and beyond.[1,2] The alliance consists of a cross-institutional collaboration among Emory University, Morehouse School of Medicine, Georgia Institute of Technology, and the University of Georgia, with a collection of interconnected programs charged with supporting and providing relevant services to investigators within those institutions. A specific aim of the Evaluation & Continuous Improvement arm of the Georgia CTSA is to assess the impact of the alliance on local, regional, and national clinical and translational science.

One way to understand the impact of a research program is through bibliometrics, or the study of supported publication portfolios. Bibliometrics describe a pivotal early stage in the translational process of bringing new scientific discoveries to clinical use. The Evaluation & Continuous Improvement program periodically evaluates the growing publication portfolio that has resulted from research supported by the Georgia CTSA. We last assessed the portfolio in 2016, finding a robust, diverse, and highly impactful portfolio compared to similar CTSA hubs.[3,4] In this update, we evaluate progress made in publication and citation activity from 2007 through 2021, including the 2017 transition from the ACTSI to the Georgia CTSA, with the addition of a novel kind of publication analysis- **altmetrics**.[5] Traditional publication impact analyses usually center on publication output, which builds the knowledge base and academic citations, and are an important early step in moving research forward toward eventual translation.[6-10] Altmetrics, on the other hand, describe the influence of published research in non-academic spheres, such as media and community discourse (e.g. news articles, blogs, Twitter), technological patents, and public health policy. Although publications are not themselves an end goal for translational endeavors, taking the further step of assessing how publications are shared and applied shines the light further down the translational pipeline.

In addition to altmetrics, we incorporate the iCite Translational Features Module,[11] which was recently developed by the NIH's Office of Portfolio Analysis, to describe the portfolio with respect to translational phase and advancement. This report goes beyond past evaluations by leveraging complementary bibliometric tools to contextualize research impact across research areas, time, and different spheres of influence. Taken together, academic citations and altmetric citations can illustrate how publications are 'making waves' that can accelerate translation. Papers with early altmetric attention can be thought of as ***big splashes*** with immediately measurable impact, whereas papers with high rates of academic citation reflect ***ripple effects*** of downstream, accumulated influence over time.

Do Big Splashes lead to Ripple Effects on Translation?

Prior research in numerous fields has investigated the relationship between altmetric scores and citation counts and found little to no association.[12-16] However, no previous research has focused on this in clinical/translational research, which aims to translate discoveries across boundaries from basic science to public use. Dissemination across academic silos and phases of the translational spectrum is expected to facilitate the interdisciplinary cross-pollination that is key to translational goals. Thus, altmetric attention that spreads findings beyond the immediate scholarly circle may engender more academic citations among researchers in adjacent fields, clinician-scientists, and public/community health researchers. Further, no previous research has elucidated the relationship between altmetrics and modern, adjusted citation impact factors like the NIH's Relative Citation Ratio (RCR),[17] which is a more sophisticated and accurate measure of citation influence that accounts for field and time since publication. It is also unclear whether any relationship between altmetric attention and citation is simply due to publication in journals with higher journal impact factors (JIF), which, by definition, are more likely to be read and cited and may drive both public attention and academic impact. Therefore, we investigated whether early altmetric indicators of *splash* are associated with citation *ripple effects* and the journal's citation impact factor.

In sum, our goal for this evaluation was to evaluate the Georgia CTSA's overall advancement in supported publication productivity from 2007 through 2021, contextualized in terms of scope and translational features, multi-institutional collaboration and interdisciplinarity, and academic influence, and further complemented by novel altmetric attention measures. The results of this report will provide a new angle on the diverse ways that Georgia CTSA-supported research is being used across both academic and non-academic circles and on how supported publications are making waves, from big splashes in early public and community attention to consequent ripple effects on academic utilization over time.

Method

Data Collection

We identified all publications formally acknowledging the Georgia CTSA as having provided support as of mid-2021. A PubMed[18] query was carried out using all past and present Georgia CTSA NIH grant project numbers (UL1 TR002378, UL1 TR000454, UL1 RR025008, KL2 TR002381, KL2 TR000455, KL2 RR025009, TL1 TR002382, TL1 TR000456, TL1 RR025010), which generated a list of **3,681** Georgia CTSA-supported publications indexed in the U.S. National Library of Medicine's MEDLINE database.

Next, in order to retrieve journal information, the list of PubMed IDs (PMIDs) was searched in Web of Science (WoS) InCites[19]; 3,416 (93%) indexed publications were found in WoS InCites, yielding a dataset that included the following for each article:

- Journal Title
- Journal Impact Factor (JIF), a proprietary InCites metric, which is an unadjusted measure of typical citation rates for the journals in which each article was published. A JIF of 5, means that the articles published in that journal in the past two years have been cited, on average, 5 times.
- Web of Science Research Area, the most granular categorization of research content available from InCites. The WoS Research Area scheme includes 252 subject categories across science, social science, arts, and humanities (not all of which are expected to be applicable to clinical/translational research). The WoS Research Area is usually assigned based upon the content area of the journal in which the article is published. If the journal is general or multidisciplinary (e.g., New England Journal of Medicine, PLOS ONE, etc.) then the article is assigned based upon its cited reference list and only assigned to the general category if no more specific designation can be made. It is typically not feasible to assign a journal/publication to a single category, therefore,

up to six research areas may be assigned to a given journal and corresponding articles, creating detailed combinations of overlapping content areas assigned to each publication.[20]

Next, in order to retrieve citation and translational feature information, the list of PMIDs was searched in the NIH Office of Portfolio Analysis's iCite application.[21] All 3,681 indexed publications were found in iCite, yielding a dataset that included the following for each article:

- The new Translational Features Module, which includes the Approximate Potential to Translate (APT),[11] or the predicted likelihood that a paper will eventually receive a clinical citation, designations as clinical papers, citations by clinical papers to date, and proportions of articles involving human, animal, and molecular/cellular research, as designated through the triangle of biomedicine.[22] The Translational Features Module was developed by the NIH since our last evaluation and the APT is, to our knowledge, the first singular metric designed to measure translation.
- The total citation count as of mid-2021
- The Relative Citation Ratio (RCR),[17] a field-normalized metric that shows the citation impact of an article relative to the average NIH-funded paper in its co-citation network. RCR data is only available for articles that are at least one calendar year old and were available for 3,167 (86%) articles as of mid-2021.

Next, to retrieve author affiliation information, the list of PMIDs was searched in Digital Science's Dimensions.[23] All 3,681 indexed publications were found in Dimensions, yielding a dataset that included the following for each article:

- All co-authors and their affiliated organizations, formatted for network analysis

Next, to retrieve altmetrics information, the list of PMIDs was searched in Digital Science's Altmetric Explorer[24] application; 2,867 (78%) indexed publications were found in Altmetric Explorer, yielding a dataset that included the following for each article:

- The Altmetric Attention Score (AAS),[5] a combined, rank order index score reflecting media and community attention paid to publications, as well use of the article in public documents. Specific components of the AAS detailed in this evaluation include references to publications in news articles, blog posts, Twitter posts, Wikipedia pages, patent applications, government and NGO policy documents, and Faculty Opinions (formerly F1000 Prime) peer faculty recommendations. The AAS also includes limited data for references in Facebook, Weibo, Google+, Reddit, and online videos. References vary in their weighted influence on the AAS depending on the relative reach of the outlet (e.g., news mentions are given the most weight when calculating AAS, whereas Facebook mentions are among the least weight).

Finally, to retrieve supplementary policy document information, from a more comprehensive set of sources than those tracked in Altmetric Explorer, the list of PMIDs was searched in the new Overton Policy[25] application; 612 (17%) indexed publications were found to be cited by a policy source tracked by Overton.

Data Analysis

Productivity, Interdisciplinarity & Influence

Portfolio Characteristics & Growth

To characterize the advancement of this publication portfolio from 2007 through 2021, we first assessed publication productivity and growth over time. We then examined the scope of this research by translational features, quantifying the proportions of human versus animal versus cellular/molecular research represented in the portfolio, the APT scores, the proportion of articles that have been cited by a clinical article, and the proportion that are themselves clinical articles. We then assessed the journal outlet and WoS Research Area frequency distributions, reporting the top ten for each. To examine interdisciplinarity, we conducted network analysis in the Science to Science (Sci2) tool,[26] creating a co-occurrence network and analyzing overlapping designations to each represented WoS Research Areas (because many papers are assigned to more than one research area based on multi-disciplinary article and journal content). We then examined national collaboration using affiliation and co-authorship data in Tableau 2019.2[27] to visualize author distribution across the United States and in VosViewer 1.6.15[28,29] (Visualization of Similarities [VOS]) to identify major clusters of research carried out by groups of co-authors.

Citation Influence

Then, to quantify the splashes and ripples made by articles in this portfolio, we calculated aggregate mean, maximum, and sum totals for journal- and article-level impact factors, and AAS components, describing sources for altmetric attention. As a complementary analysis, we used the new Overton Policy database to assess the proportion of articles that have been cited by policy documents and describe the sources. Finally, we identified case example articles that reflect particularly high impact splashes and influential ripples and present infographic illustrations of the impact made by these articles.

To test the hypothesis that altmetric attention is predictive of citation influence independent of the effect of the journal's impact, we drew on previously saved datasets collected in mid-2020 for the AAS and its subcomponents and collected at the end of 2020 for the JIF (reflecting citation impact calculated over the previous two years). We combined this data with up-to-date iCite citation data in order to predict current citation status from older JIF and AAS. For publications to be included in analysis, it was necessary to have the AAS available from Altmetric Explorer in mid-2020, the JIF available from InCites at the end of 2020, and the RCR available from iCite in September 2021, including scores of zero. Because the RCR is only calculated for articles more than one year old, which allows time for the accrual of sufficient citation network data, all publications in this subset were published prior to September 2020. A total of 2,188 publications met all criteria to be included in analyses.

To contextualize relationships among variables in this evaluation, we conducted Spearman's rank order correlation analyses among the 2020 AAS and its subcomponents, 2020 JIF, and 2021 RCR, total citations, and APT. We assessed relative effect sizes and statistical significance of the correlation coefficients. All analyses were conducted in SPSS version 27.[30]

Results

Productivity, Interdisciplinarity & Influence

Portfolio Characteristics & Growth

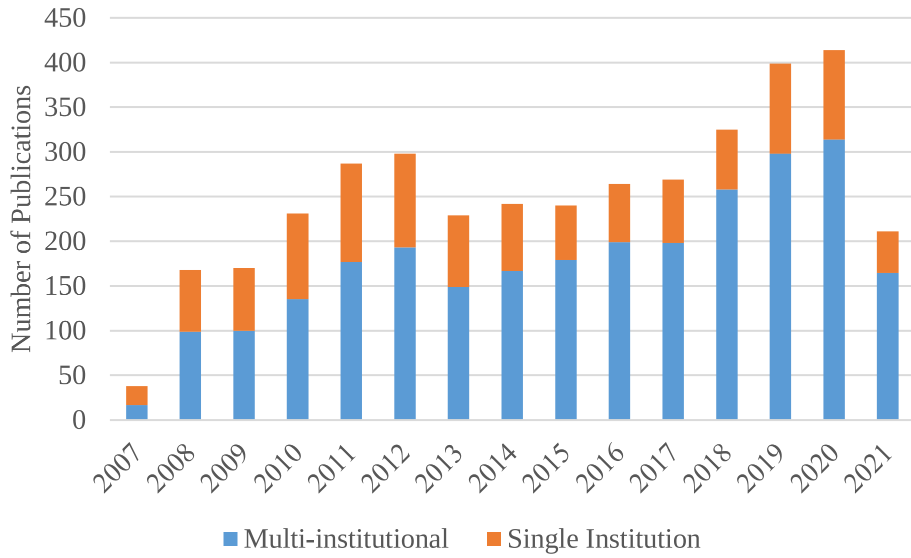


Figure 1. Total number of Georgia CTSA-supported publications, and proportion that are multi-institutional, by year

Results revealed the myriad ways that Georgia CTSA-supported research is making waves of impact through publications. First, a ‘tsunami’ of **3,681** supported articles has been published over the past 13 years. Of these, **2,649** (72%) articles were multi-institutional, including 232 that were co-authored across the four Georgia CTSA institutions and 734 that were co-authored across the national CTSA consortium of hubs. The past four years since the transition from the ACTSI to the Georgia CTSA has seen a steady increase in publication productivity as well as an increase in the proportion of multi-institutional articles over time (see **Figure 1**). Since the last bibliometric evaluation at the end of 2016, the average rate of publication has increased from 231 per year to 324 per year.

Results from the recently developed iCite Translational Features Module showed that across the Triangle of Biomedicine 79% of the articles involve human subjects, 14% involve cellular/molecular

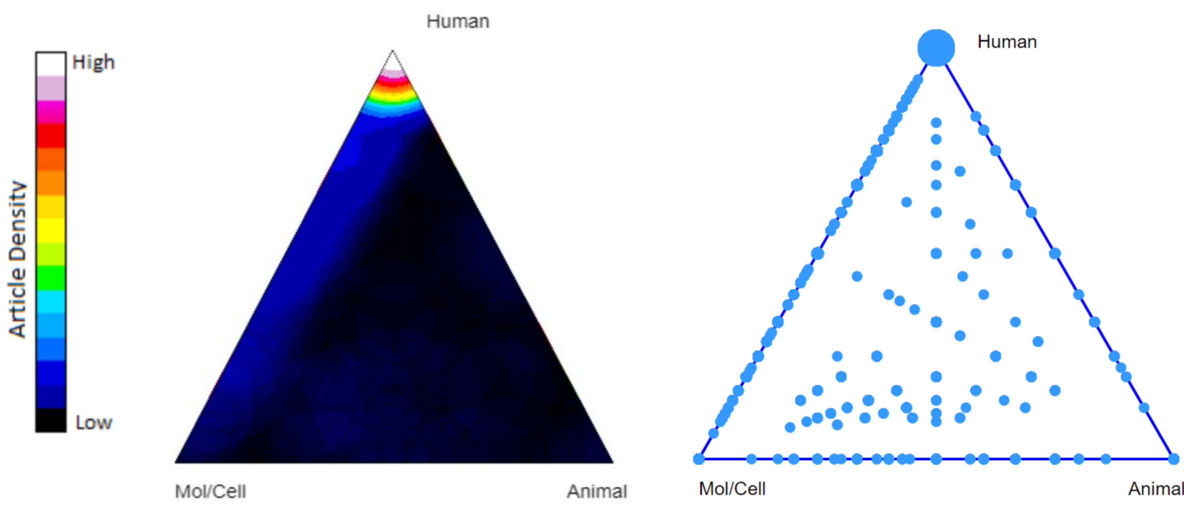


Figure 2. Distribution of Georgia CTSA-supported publications across the Triangle of Biomedicine

research, and 6% involve animal research (see **Figure 2** for visualizations of the triangle of biomedicine from iCite). The mean APT score for the portfolio is 0.51, meaning that on average, there is a 51% likelihood that articles in this portfolio will be translated to clinical use by being cited by a clinical article. Consistent with this, 47% of the articles have been cited by clinical articles thus far, and 15% are themselves clinical articles.

Content & Scope

Articles in this portfolio were published in 1,086 different journals, ranging across 129 different WoS Research Areas. The top ten most frequently represented journals and WoS Research Areas, along with their respective impact factors, are listed in **Table 1**.

Table 1. Top 10 most frequently represented journals & Web of Science (WoS) Research Areas in the Georgia CTSA publication portfolio

10 Most Frequent Journals:	**# Articles**	**Journal Impact Factor (JIF)**
PLOS ONE	76	3.24
Journal of Acquired Immune Deficiency Syndrome	51	3.73
AIDS	50	4.18
Clinical Infectious Diseases	50	9.08
Diabetes Care	47	19.11
Pediatrics	38	7.12
Critical Care Medicine	35	7.60
New England Journal of Medicine	35	91.25
Journal of Allergy and Clinical Immunology	30	10.79
Journal of Pediatrics	29	4.41
10 Most Frequent WoS Research Areas:		**Article Impact Factor (Mean RCR)**
Immunology	419	3.18
Infectious Diseases	352	1.85
Public, Environmental & Occupational Health	269	1.50
Endocrinology & Metabolism	246	2.33
Cardiac & Cardiovascular Systems	242	2.01
Neurosciences	241	3.91
Psychiatry	240	4.19
Pediatrics	207	3.56
Microbiology	139	2.67
Clinical Neurology	132	2.43

Network analyses of overlapping WoS Research Areas assigned to the same articles reveal the many diverse WoS Research Areas that are connected by publications in this portfolio. On average, research areas were connected to seven other areas. Due to the dense visual complexity of the full network, we depict interdisciplinarity of the top 50 most frequently represented research areas only in **Figure 3**.

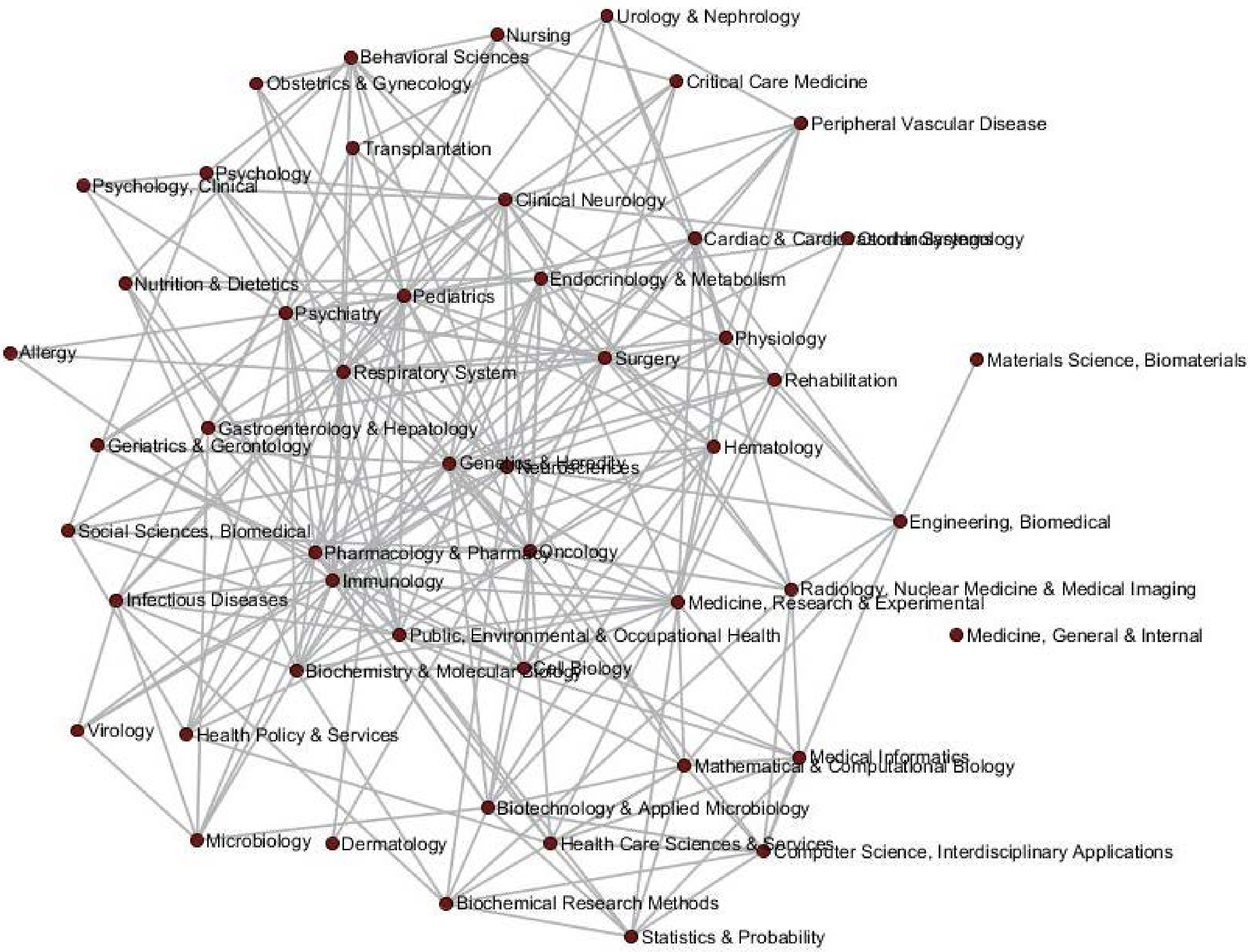


Figure 3. Interdisciplinary overlap among the top 50 most frequently represented Web of Science (WoS) Research Areas in the Georgia CTSA publication portfolio

Co-authorship

Approximately 18K co-authors came from approximately 2K different institutions across the United States and 82 other countries. The geographic distribution of the most frequent authors' affiliated institutions (those with ten or more publications) in the United States is depicted in **Figure 4**, with larger circles indicating more authors at that location. Although the map shows that the majority of authors came from Georgia, significant representation spans across the country.

Figure 4. Geographic distribution across the United States for authors in the Georgia CTSA publication portfolio

Combining authorship with content, the network of most frequent co-authorship clusters is depicted in **Figure 5**. This visualization includes 477 authors who have co-authored more than ten publications in the portfolio. Colors indicate cohesive clusters of collaborative work and lines indicate co-authorship both among and between clusters. The five largest clusters included infectious disease, epidemiology, cardiovascular disease, psychiatry, and pediatrics.

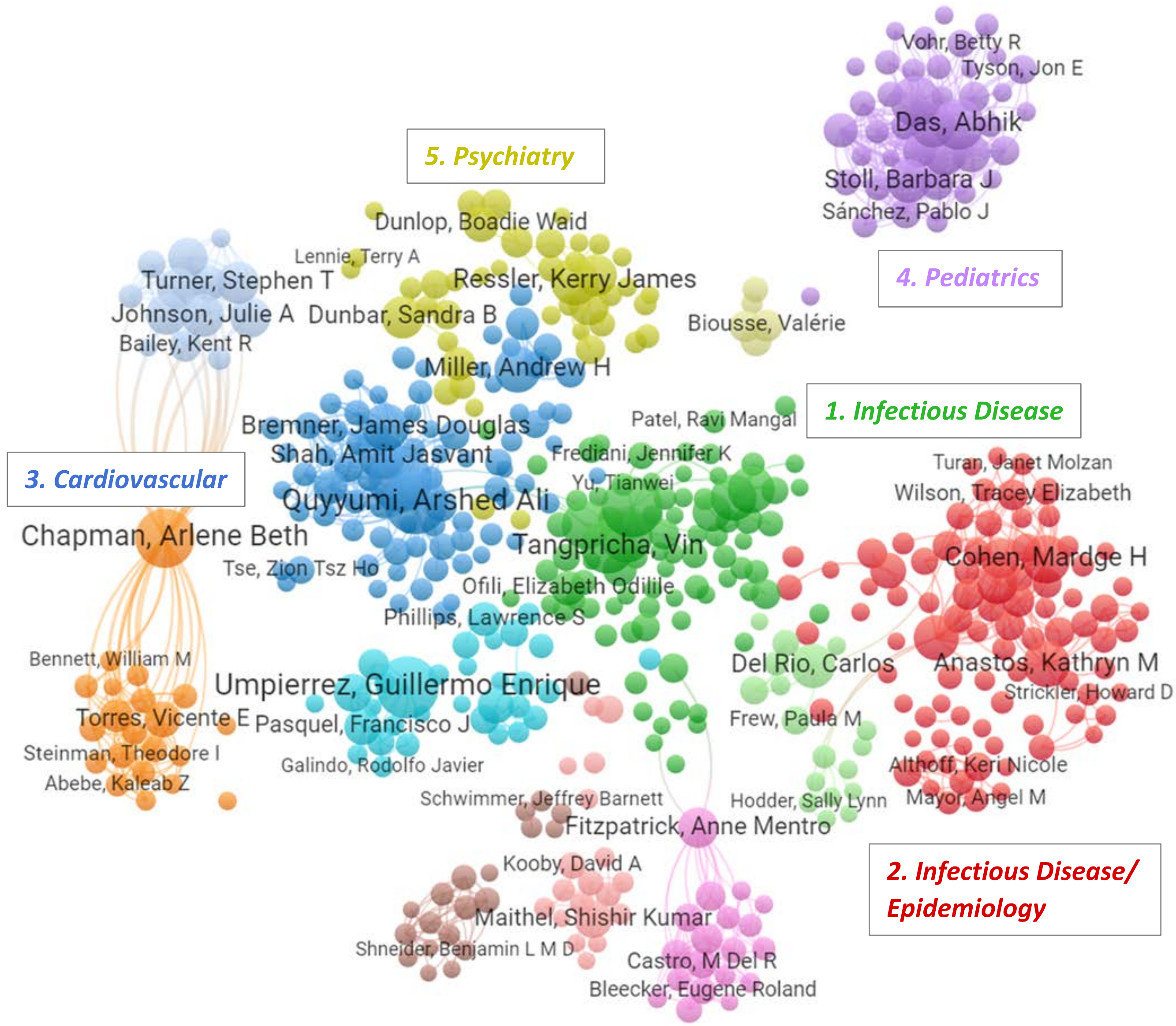


Figure 5. Network of top co-author collaborative research clusters represented in the Georgia CTSA publication portfolio

Citation Influence

Next, with regard to utilization of these publications, results showed how they have made waves within both academic and public spheres. Of the **3,681** articles, 3,355 (91%) had at least one academic citation and 2,488 (68%) had some form of altmetric attention. These articles have accumulated almost 150K academic citations, for an average of over 40 citations per article. The average RCR value of 2.5 (median = 1.2) means that these articles have been cited an average of 2.5 times as often as other articles from the same year and field. This is an increase from the 2016 evaluation which found an RCR of 2.4

and a rate of approximately 6,500 citations per year in the first 9 years, versus 10,600 citations per year now.

These publications have also accumulated over 65K references in altmetric sources with the number of mentions and the AAS increasing over time. Some of the most frequent altmetric sources include the Twitter account *HIV_Insight*, the news outlet *MedicalXpress*, the blog *Physician's Weekly*, and the policy source the *World Health Organization*. **Table 2** summarizes findings for metrics that reflect splashes and ripples among the Georgia CTSA's supported publications, including, if applicable, the mean across articles, the maximum for any one article, and the sum across articles. Further analyses showed that according to the new but more comprehensive Overton Policy database, 611 (17%) of the articles have been cited by a policy document, with a total of 1,400 references in international policy sources. Most frequent policy sources in Overton included Guidelines in Pubmed Central, the World Health Organization, and the Centers for Disease Control and Prevention.

Table 2. Academic citation metrics & altmetrics in the Georgia CTSA publication portfolio

	Mean	***Max***	***Sum***
Journal Impact Factor (JIF)	7.9	91.25	n/a
Big Splashes			
Altmetric Attention Score (AAS)	25	14,655	71,877
Altmetric references in:			
News stories	n/a	1,373	5,807
Blog posts	n/a	141	943
Twitter posts	n/a	17,370	53,982 (to > 80M followers)
Faculty Opinions recommendations	n/a	6	208
Wikipedia pages	n/a	10	269
Patent applications	n/a	209	1,333
Policy documents	n/a	8	476
Ripple Effects			
Academic citations	40.55	4,823	148,900
Relative Citation Ratio (RCR)	2.49	260.4	n/a

Using the suite of metrics summarized in Table 2, we identified specific publications that represent case examples of a big splash[31] and strong ripple effects.[32] **Figure 6** presents these cases via infographic illustrations that include details of the support provide and the sources of impact.

Big Splashes with Immediate Impact

PUBLICATION SPOTLIGHT

Transmission of Extensively Drug-Resistant Tuberculosis in South Africa

published in *The New England Journal of Medicine* in 2017

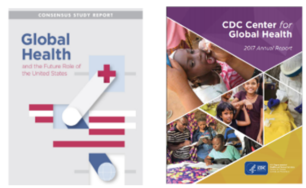
Research that changed public discourse and academic understanding of how deadly strains of infectious disease are spread; implications for prevention and hospital practice

Appeared in **68** news stories

npr

The New York Times

Cited in **6** policy documents



Recommended by peers on **F1000 Prime** & **PubPeer**

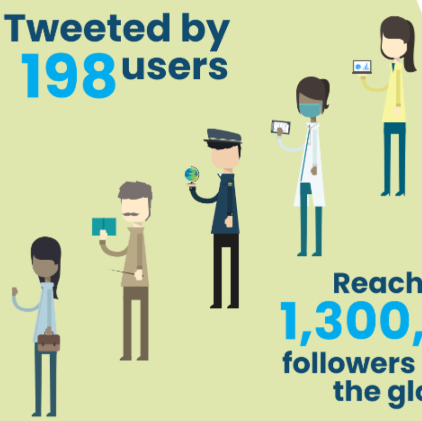
Referenced in **4** academic blogs

Author Sarah Auld, MD, MSc received Georgia CTSA program support in:

- Clinical Research
- Biostatistics
- Informatics

Spreading the Word

Tweeted by **198** users



Reaching **1,300,000** followers across the globe

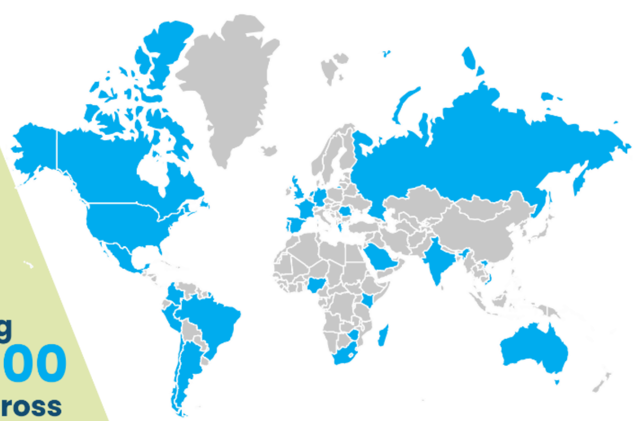


Figure 6. Infographic illustrations of an article with a big splash and an article with ripple effects in the Georgia CTSA publication portfolio

Big Splashes associated with Ripple Effects

Table 3 presents a Spearman's rho correlation matrix for the altmetrics, JIF, and iCite citation metrics, among the subset of publications for which there were all necessary data. Results showed that the AAS, JIF, and RCR were all positively and significantly correlated with one another, with medium effect sizes. The AAS was more strongly associated with the RCR than with total citations, JIF, or APT. Further, correlation analyses with AAS subcomponents indicate that the AAS was most strongly related to News, Twitter, and Blog mentions, suggesting that the AAS score is largely driven by these subcomponents, which also typically have among the most mentions. The JIF and RCR were most strongly related to News and Blog mentions, and the APT was most strongly related to Policy mentions.

Table 3. Intercorrelations among altmetrics, JIF, and iCite citation metrics in the Georgia CTSA publication portfolio

n=2,188	AAS	JIF	RCR	APT	Total Citations
JIF	$.35^{***}$				
RCR	$.41^{***}$	$.41^{***}$			
APT	$.30^{***}$	$.29^{***}$	$.78^{***}$		
Total Citations	$.27^{***}$	$.40^{***}$	$.88^{***}$	$.74^{***}$	
News mentions	$.63^{***}$	$.29^{***}$	$.31^{***}$	$.22^{***}$	$.24^{***}$
Blog mentions	$.50^{***}$	$.27^{***}$	$.32^{***}$	$.23^{***}$	$.29^{***}$
Policy mentions	$.25^{***}$	$.12^{***}$	$.27^{***}$	$.28^{***}$	$.30^{***}$
Patent mentions	$.22^{***}$	$.20^{***}$	$.27^{***}$	$.14^{***}$	$.35^{***}$
Twitter mentions	$.71^{***}$	$.25^{***}$	$.22^{***}$	$.17^{***}$	-0.002*ns*
Wikipedia mentions	$.21^{***}$	$.11^{***}$	$.20^{***}$	$.13^{***}$	$.23^{***}$
F1000 mentions	$.16^{***}$	$.24^{***}$	$.24^{***}$	$.18^{***}$	$.24^{***}$

***= p<.001

Conclusions

The purpose of this evaluation was to systematically evaluate the impact of the Georgia CTSA-supported publication portfolio between 2007 and 2021. This evaluation delivers a comprehensive and nuanced understanding of the research scope and collaborative patterns of supported research, and the short- and long-term impact of the supported research through cutting-edge bibliometrics, including altmetric methods.

Summary

This evaluation reveals the considerable advancement in published research supported by the Georgia CTSA since the inception of the program in 2007, and especially since the last grant renewal in 2017. In Part 1, results show that the publication rate has accelerated, and that multi-institutional research has been on the rise since the expansion from the ACTSI to the Georgia CTSA. Analyses of content and scope describe the focus of the research on human subjects and the likelihood of translation of the work to clinical research reflected in the newly developed iCite Translational Features Module. Publications in this portfolio have been published in diverse outlets including both broadly reaching multi-disciplinary journals (e.g., PLOS ONE, New England Journal of Medicine) and prominent disciplineand disease-specific journals (e.g., Diabetes Care, Pediatrics). Predominant research areas included infectious disease, cardiovascular disease, psychiatry, and pediatrics, but network analyses show that many diverse research areas overlap to a significant degree. Results of co-authorship analyses further illustrate how researchers have collaborated across the country, the world, and research areas to advance clinical and translational science.

We next used state-of-the-art bibliometric tools to provide new insights into the diverse ways that Georgia CTSA-supported research is being used across both academic and non-academic circles. In 2016 we found the portfolio garnered academic citation influence well above average, a pattern that has continued and even increased, with significantly more publications and citations per year than was seen in the previous evaluation. Outside of traditional academic citation, this is the first report of novel altmetrics for the Georgia CTSA's publication portfolio. This new perspective on publication influence shows how published research has made splashes in forums such as the news, blogs, and Twitter, influencing public discourse among scientific organizations, researchers in the same or related fields, patients, and the general public. Other altmetric attention, such as Wikipedia, policy document, and patent references reflect use of articles to advance public knowledge, technology, and policy. Although these types of references often appear later and may be more indicative of ripples than splashes, they do sometimes manifest soon after an important article is published, and they are more rare and less strongly weighted than media sources and thus are less likely to drive the AAS. Importantly, these metrics can be used separately or in concert to understand early impact and quality (e.g., via peer faculty recommendations or policy use) as well as lingering influence on translation (e.g., longer-term patent/policy use and academic citation) for a portfolio or individual articles, as demonstrated in case example infographics.

Limitations & Future Directions

One limitation of the relatively new altmetrics is that, while extensive, the metrics from Altmetric Explorer cannot be exhaustive of all altmetric attention paid to research articles. Media communication is vast, ever-evolving, and sometimes ephemeral. We deliberately chose to focus on some of the most salient and well-tracked media platforms available (e.g., Twitter, Wikipedia), but the AAS has additional, albeit, limited data from platforms such as Facebook, Google+, and Reddit, which we did not attend to in our analysis due to their low weighting in the AAS and in the interest of more concise interpretability.

Strengths of this evaluation include novel methods and comprehensive perspectives which speak to the growing impact of this research across disciplines, the nation, and spheres of influence. Further, to our knowledge, this is the first analysis to investigate the relationship between altmetric influence and subsequent academic citation using a modern, adjusted citation impact factor rather than raw citation count.

Conclusion

In sum, the findings of this evaluation demonstrate the considerable impact of research supported by the Georgia CTSA. This evaluation demonstrates how supported publications are making waves, from big splashes in early public and community attention to consequent ripple effects on academic use over time. We view this as evidence for a chain of events where translatable research is supported by the

Georgia CTSA, that research is published in academic journals, some that are very high impact. Those publications are then discussed and referenced in non-academic and community forums, and the more that happens the more likely they are to be used and cited in subsequent research, which we think opens the door to moving medical science forward toward usable technological and translational advancement.

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