Big Splashes & Ripple Effects:

An Evaluation of the Short- & Long-term Impact of the Georgia CTSA Pediatrics Program from 2007-2020

Internal Report

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Executive Summary

Background:

The purpose of this evaluation was to systematically evaluate the impact of the Georgia Clinical and Translational Science (Georgia CTSA) Pediatrics Program through the products that have emerged from supported research between 2007 and 2020. Several complementary approaches, including bibliometric, altmetric and geospatial analyses, combine to shed light on both the short- and long-term impact of this research on: academic literature, community discourse, technological advancement, and public health policy; as well as statewide reach and impact. This report will aid in characterizing the contributions to clinical and translational science that have been made possible by research supported by the Georgia CTSA's Pediatrics Program.

Method:

The Evaluation & Continuous Improvement team used internal records of Georgia CTSA services provided (clinical and expert support, pilot and training grants), and formal acknowledgement of grant support in peer-reviewed scientific publications to define a portfolio of **250** pediatric articles published by 93 Georgia CTSA-supported investigators from 2007-2020. In **Part 1**, we describe this publication portfolio in terms of breadth of content, authorship, and collaboration. In **Part 2**, we assessed short-term impact, or '*splash*' made by an article, via journal status, peer recommendations, readership, and non-academic 'altmetric' measures of media and community attention. Then, we assessed long-term impact, or '*ripple effects*' of an article, via accrued citations in subsequent academic products and public documents. Finally, in **Part 3**, we assessed geographic spread of pediatric research participants across Georgia, and the impact of the research to which they contributed.

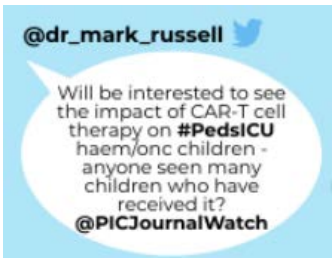
Results:

Part 1. The Big Picture: Research Scope and Collaboration

The 250 Georgia CTSA-supported pediatrics articles were published at a steady rate across the past 13 years. Across the translational spectrum, most articles involved human subjects (89%) and the T2/T3 (53%) phases of translation. Of the 250 publications, 148 (59%) have been translated to clinical research use (cited by a clinical article) and 68 (27%) have been translated to policy use (cited in a policy document). The articles were published in 112 different journals, most frequently: *Pediatrics*, *The Journal of Pediatrics*, and *Journal of Allergy and Clinical Immunology*. They cover 44 Web of Science Research Areas, most often Pediatrics, but with the most frequent field-specific areas being: Immunology, Allergy, and Oncology. In addition to NCATS, the articles were supported by 110 funding bodies, most often: NICHHD, NIDDK and NHLBI. Georgia CTSA authors collaborated with more than 1,500 other authors across 236 institutions. Significant clusters of research conducted by repeated co-author collaborations included research on: **premature infants, childhood asthma, liver/kidney disease, and autism**.

Part 2. Big Splashes and Ripple Effects: Short- and Long-term Impact

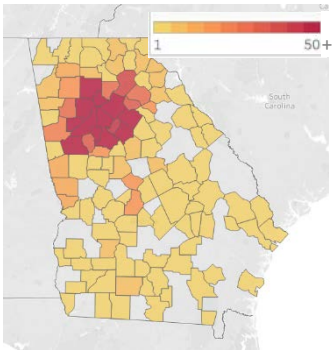
The short-term impact of this portfolio is indicated through academic measures including publication in high-impact journals (mean JIF = 8), 19 peer faculty recommendations, and over



15,000 reader downloads on Mendeley, all of which reflect academic exposure and potential for future citations. Early interest in the research is also indicated by altmetric attention, including references in 365 news stories, 73 blog posts, and 4,494 Twitter posts to over 17 million followers. The long-term impact of this portfolio is demonstrated by high absolute and relative rates of academic citation over time (10,819 total citations; mean Relative Citation Ratio = 3.3), as well as by altmetric attention that reflects downstream influence in public-facing documents, including references in 4 Wikipedia articles, 16 patent applications and 33 policy documents.

Some illustrations of big splashes with short-term impact include: a 2019 article on adolescent fatty liver disease that appeared in the New York Times and in 600 tweets to over 2 million followers; and a 2018 article on T-cell therapy for leukemia that appeared in 8 science blogs and in news outlets around the world (e.g. BBC News, Deutsches Arzteblatt, MedIndia). Illustrations of ripple effects with long-term impact include: a 2011 article on sugar consumption that was cited in multiple CDC policy reports; and a 2012 article on a new treatment for kidney disease that led to patents for its formulation and manufacture.

Part 3. Statewide Reach: Impact Across Georgia



The Georgia CTSA has supported pediatric research with participants from hometowns across Georgia and even across the nation. Pediatric participants hailed from 5 countries, 38 states, 106 of 159 Georgia counties, and 349 of 953 Georgia zip codes. Almost 5,000 research participants contributed to 175 different studies across fields of pediatric research, the most frequent of which were: 2,293 participating in **Infectious Disease** research (e.g. flu & RSV), 817 participating in **Pulmonology** research (e.g. asthma & cystic fibrosis), 437 participating in **Psychiatry** research (e.g. depression & PTSD), and 395 participating in **Nephrology** research (e.g. polycystic kidney disease) & 390 participating in **Endocrinology** research (e.g. diabetes).

Conclusions:

The findings of this evaluation demonstrate the considerable waves of impact made by the research that the Georgia CTSA Pediatrics program supported. We found a breadth of interdisciplinary research content addressed over the past 13 years and identified several focused areas of research. The short-term splashes and long-term ripples depicted by both academic bibliometrics and community altmetrics tell the story of the pediatrics program's research impact in ways that go further than traditional citation measures and inform our understanding of how these research products are being used and translated in both the academic and broader community. Short-term splash provides a picture of early interest shown to a publication, a preliminary indicator of the eventual utility and impact that research is expected to have. Long-term ripples provide a measure of the extent of downstream influence an article has had over time. Both reflect opportunities for a line of research to move forward along the translational spectrum. Finally, geospatial mapping of pediatric research participants confirms the statewide scope of impactful and diverse research that has been supported by the Pediatrics program.

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. 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. One such program is the Georgia CTSA Pediatrics Program, a longstanding effort to transform scientific discovery into solutions that improve pediatric health. The program trains researchers, provides pilot funding, and ensures that research projects have the resources needed to move forward. 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. Previous evaluations of Georgia CTSA pediatric research output found a body of work that is highly impactful within the academic community, compared to similar work at other institutions [1,2]. Moreover, pediatrics research is unique in its coverage of diverse fields of study and in its particular interest to the broader community. Therefore, we chose to systematically examine the impact of the research supported by the program in both academic and community spheres. Additionally, because the Georgia CTSA aims to equitably address pediatric health across both urban and rural Georgia, we also examined the statewide extent of this research.

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. Past research has been limited in its ability to directly connect support provided to bibliometric research outputs, and in contextualizing impact over time [3,4]. This report goes beyond past research by meticulously evaluating Georgia CTSA support provided to investigators conducting pediatric research, and by using complimentary bibliometric tools to understand both short-term attention and long-term influence, in both academic and public forums, associated with resulting publications. In addition to studying bibliometric output, we incorporated geospatial data on individuals who participated in the research that is reflected in some of these publications, in order to assess the geographic reach of the program.

This evaluation was carried out in three parts:

Part 1. The Big Picture: Research Scope and Collaboration

The aim of Part 1 is to comprehensively describe the content of the pediatric research carried out by Georgia CTSA-supported investigators across 13 years of operations. Identifying the predominant subjects addressed by Georgia CTSA-supported research aids in understanding the focus and diversity of pediatric research supported. In addition, examining the overlapping research areas designated to the same articles illuminates the degree to which the Georgia CTSA is reaching the goal of supporting collaborative, inter-disciplinary pediatric research.

Results of Part 1 will first describe features of the portfolio as they pertain to advancement along the translational spectrum. Second, results will define the overall distribution of journal outlets and research content areas represented in the pediatric publication portfolio. Third, results will elaborate on the inter-disciplinary structure of the publication portfolio, by examining the co-designations of research areas to the

same publications, as well as co-funders of the research. Finally, co-authorship analyses will depict the national collaborative structure reflected in the portfolio, including major clusters of study.

Part 2. Big Splashes and Ripple Effects: Short- and Long-term Impact

The aim of Part 2 is to delineate both short-term and long-term impact of the articles according to patterns reflecting 'big splashes' or short-term, immediate, and enthusiastic forms of impact, and 'ripple effect' or long-term, accumulating, and lingering forms of impact. We combine both established academic citation metrics and non-traditional 'altmetrics', or non-academic forms of public attention to publications, to form a comprehensive bibliometric evaluation. We utilized measures of short-term splash including journal impact factor, faculty recommendations, and Mendeley reader downloads, all of which reflect academic exposure and potential for future citations, and components of the Altmetric Attention Score [5] that reflect early community interest in the form of references in news stories, blog posts, and Tweets. We utilized measures of long-term ripples including absolute and relative rates of academic citation over time, as well as components of the AAS reflecting downstream community influence in the form of references in Wikipedia, patent applications, and public health policy documents. Part 2 will summarize overall and average citation impact metrics and altmetrics, and provide several case illustrations of articles that have made big splashes and had broad ripple effects.

Part 3. Statewide Reach: Impact Across Georgia

The aim of Part 3 is to depict the statewide reach and distribution of Georgia CTSA-supported pediatric research over time. In this analysis, we employed geospatial analysis for all pediatric research participants who took part in research at the Georgia CTSA Clinical Research Centers (GCRCs). We plotted home zip code data for these participants across time to understand the growth in statewide scope. In addition, we examined the statewide spread for participants of different trials and areas of study.

In sum, this report is intended to systematically characterize the contributions to clinical and translational science that have been made possible by research supported by the Georgia CTSA's Pediatrics Program. Using complementary approaches, we will report on the products that have emerged from supported research from the inception of the program in 2007 to the present. The results of this report will shed light on the content, scope, and the short- and long-term impact of this research on: academic literature, community discourse, technological advancement, and public policy; as well as statewide reach and impact.

Method

Data Collection

In fall 2019, internal records were queried in the Georgia CTSA internal tracking system Request and Progress Information Database (RAPID) for instances of program support received by pediatric researchers and other researchers collaborating on pediatric research, since the inception of the Georgia CTSA in 2007. A total of 224 Georgia CTSA investigators (predominantly from Emory University and Children's Healthcare of Atlanta) and 988 instances of support were identified (predominantly clinical support from the GCRCs and expert support from BERD and Informatics). Publications arising from this support being the central impact outcome under

study, these investigators were cross-referenced with Georgia CTSA grant-citing publications queried from PubMed. Specifically, we selected publications that met the following inclusion criteria:

(1) Acknowledged the Georgia CTSA as having provided support

   i. A PubMed [6] query was carried out using all past and present Georgia CTSA-specific NIH grant project numbers (UL1 TR002378, UL1 TR000454, UL1 RR025008, KL2 TR002381, KL2 TR000455, KL2 RR025009, TL1 TR002382, TL1 TR000456, TL1 RR025010), as well as their common variants. This generated a list of 2,941 Georgia CTSA-supported publications indexed in the U.S. National Library of Medicine's MEDLINE database [7].

(2) Authored by one of 224 pediatric researchers who received support

   i. Received support from CTSA Pediatrics program, or affiliated with Children's Healthcare of Atlanta, a pediatrics department, or listed as having pediatric expertise

(3) Containing clear pediatric content

   i. Pediatric keywords appearing in any of the following: Journal title, Article title, MESH terms, Web of Science Research Area
      - Keywords searched: pediatric/paediatric, child, youth, infan-, natal, adolescen- (when not appearing with 'Adult' MESH term, to exclude 18+ studies)
      - Additional key words were searched (e.g. teen, school) but returned no additional relevant results
      - Resulting publications were individually inspected for misattributed/aberrant keyword results

A total of 250 publications met these inclusion criteria and were included in further analyses (see Appendix 1 for a full listing of included publications). These publications were authored by 93 (of the 224) Georgia CTSA investigators who received 630 instances of support, and were published at a steady rate over the past 13 years.

Next, in order to retrieve journal and content information, the list of PubMed IDs (PMIDs) was searched in Web of Science (WoS) InCites [8,9] in 2020; 236 indexed publications were found in WoS InCites, yielding a dataset that included the following for each article:

- The **Journal** and **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, for instance, means that the articles published in that journal in the past two years have been cited, on average, 5 times.

- The **Web of Science Research Area (WoSRA),** the narrowest categorization of research content available from InCites, offering the most granular information on content area. Using such specific subareas allows for the most appropriate comparisons of articles to one another based upon shared classification. 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 Georgia CTSA-supported pediatric 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, PlosOne, 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/article, creating detailed combinations of content areas assigned to each publication [10].

Next, in order to retrieve citation and translational feature information, the list of PMIDs was searched in the National Institutes of Health's (NIH) iCite application [11] and the Overton database [12] in 2020. All 250 indexed publications were found in iCite, yielding a dataset that included the following for each article:

- **Translational features module**, including the **Approximate Potential to Translate (APT**), or the predicted likelihood that a paper will eventually receive a clinical citation, as well as designations as clinical papers and citations by clinical papers to date. In addition, we collected the percentages of research involving human, animals, and molecular/cellular research as designated through the triangle of biomedicine [13], and we manually designated T0-T4 translational phase status to each article based on article title and abstract [14].
- The total **citation count** as of 2020
- The **Relative Citation Ratio (RCR)** [15], 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 PMIDs that are at least one calendar year old and was available for 231 articles as of mid-2020.
- All **policy document references** found in the Overton database as of 2020

Next, to retrieve author, funding, and altmetrics information, the list of PMIDs was searched in Digital Science's Dimensions [16] in 2020. All 250 indexed publications were found in Dimensions, yielding a dataset that included the following for each article:

- All **co-authors** and their affiliated organizations
- All **funding sources** acknowledged by the authors
- The **Altmetric Attention Score (AAS)** [5], a combined index score reflecting all early media and community attention paid to a published article as well as use of the article in subsequent public documents. Specific components of the AAS detailed in this study include references to publications in: news articles, blog posts, Twitter posts, Wikipedia pages, patent applications, government policy documents, and also, F1000 Prime faculty recommendations and Mendeley reader downloads. In addition to references to publications in patent applications, we also collected information on patent applications authored by Georgia CTSA pediatric investigators.

Finally, in addition to publication impact analysis, in late 2020, we collected geospatial data for all pediatric clinical trials supported by the CTSA to understand statewide impact of the research. We drew internal records for participants under the age of 21 who took part in pediatric research conducted at the (GCRCs), including zip codes, birthdate, visit date, study title, and principle investigator.

Data Analysis

Part 1. The Big Picture: Research Scope and Collaboration

In order to characterize the content of the pediatric publication portfolio, we first assessed the scope of this research along the translational spectrum, utilizing the iCite Translational features module to quantify the proportions of human versus animal versus cellular/molecular research represented in the portfolio, the APT scores and proportion of articles that have been cited by a clinical article, the proportion that are themselves

clinical articles, and the proportions of articles corresponding to manually coded translational phase designations from T0 to T4. In addition, we used the Overton database to assess the proportion of articles that have been cited by any policy document. Next, we assessed research area content via that number of articles published in each journal, along with journal impact factors for context, and the number of articles assigned to each WoSRA. Then, in order to assess interdisciplinarity, we conducted network analysis in the Science to Science (Sci2) tool [17] depicting the overlapping designations to each represented WoSRA (because many papers are assigned to more than one WoSRA based on multi-disciplinary article and journal content) and examined the areas that overlapped with pediatrics. We also examined content overlap by assessing the most frequently represented funding bodies, in addition to NCATS, that supported these publications. Finally, we examined national collaboration using affiliation and co-authorship data in VosViewer 1.6.15 (Visualization of Similarities [VOS]) [18] to identify major clusters of research being carried out in repeated collaborations among institutions from across the country.

Part 2. Big Splashes and Ripple Effects: Short- and Long-term Impact

In the second phase of analyses, in order to quantify the splashes and ripples made by articles in this portfolio, we examined aggregate mean, maximum, and sum totals for journal- and article-level impact factors, Mendeley downloads, and Altmetric Attention Score components. In order to provide context, we describe sources for altmetric attention, readership, and citation. In addition to publication references made in patent applications (which may not necessarily be connected to a Georgia CTSA author) we used internal records to assess any patent applications that were themselves authored by a supported pediatric author. 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.

Part 3. Statewide Reach: Impact Across Georgia

In the last phase of analysis, in order to understand statewide scope of the pediatric supported research, we conducted geospatial mapping analysis using zip codes of pediatric participants under the age of 21 who took part in pediatric clinical research supported by the Georgia CTSA, which forms the basis for some of the publications within the portfolio of 250. We used Tableau Version 2019.2 [19] to visualize the extent of Georgia counties and zip codes from which participants were drawn, as well as locations outside of Georgia, cumulatively across the years. We then contextualized the types of research conducted with participants from different locations across Georgia.

Results

Part 1. The Big Picture: Research Scope and Collaboration

Across the translational spectrum, most of the 250 focal articles involve human subjects (89%), with only 8% involving cellular/molecular research, and 1% involving animal research. Most of the research fell into either the T2/T3 (53%) phases of translation, which include research intended to improve treatments, therapies, and protocols for particular health problems, or the T0/T1 (39%) phases of translation, which include basic and foundational research intended to elucidate correlates, mechanisms, and molecular underpinnings of health problems [14]. The mean APT score for the portfolio was .67, meaning that on average, there is a 67% likelihood that articles in this portfolio will be translated to clinical use by being cited by a clinical article.

Consistent with this, 148 (59%) of the 250 articles have been cited by clinical articles thus far, and 62 are themselves clinical articles. Further, 68 (27%) have been cited by a policy document in the Overton database.

The 250 publications were published in 112 different journals, ranging across 44 different WoSRAs. The top ten most frequently represented journals (along with JIFs) and WoSRAs are listed in Table 1. The most common WoSRA designation by far was Pediatrics, which was designated to 104 (42%) articles (articles published in field-specific and not pediatric-specific journals will hold the corresponding WoSRA designations and not necessarily be designated as pediatric; all articles in this portfolio are, however, pediatric in content). Network analyses show that many diverse WoSRAs overlapped with the Pediatrics designation and with one another (see Figure 1). In addition to WoSRA overlap, we found that while all articles were funded by NCATS (which is obligatory given our inclusion criterion to cite the Georgia CTSA), many were funded by additional funding bodies, most frequently NIH agencies including the National Institute of Child Health and Human Development (NICHHD; 66 articles), the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK; 52), and the National Heart, Lung and Blood Institute (NHLBI; 48).

A total of 1,550 co-authors came from 236 different institutions across the US, as well as 16 other countries. The distribution of authors' affiliated institutions in the US are depicted in Figure 2a, along with one example network for the most prolific collaboration in the portfolio (research on premature infants). The network of most frequent co-authorships (of at least 5 publications) is depicted in Figure 2b, with major cohesive clusters of collaborative work including: premature infants (51 publications), childhood asthma (37), liver (24)/kidney (19) disease, and autism (13).

Table 1. Most Frequently Represented Journals & Web of Science Research Areas (WoSRAs)

Most Frequent Journals:	**# Articles Published**	**Journal Impact Factor**
Pediatrics	21	5.4
The Journal of Pediatrics	20	3.7
Journal of Allergy and Clinical Immunology	18	14.1
Pediatric Blood & Cancer	8	2.5
Journal of Pediatric Gastroenterology and Nutrition	8	3.0
Pediatric Research	7	2.9
The Journal of Allergy and Clinical Immunology in Practice	7	7.6
Clinical Journal of the American Society of Nephrology	7	6.2
JAMA	7	51.3
PLoS ONE	6	2.8
Archives of Disease in Childhood-Fetal & Neonatal Edition	5	3.8
New England Journal of Medicine	4	70.7
Most Frequent WoSRAs:		
Pediatrics	104	
Immunology	42	
Allergy	27	
Hematology	23	
Nutrition & Dietetics	16	
Gastroenterology & Hepatology	16	
Urology & Nephrology	16	
Infectious Disease	14	
Oncology	11	
Endocrinology & Metabolism	10	

Figure 1. Web of Science Research Area (WoSRA) Inter-disciplinary Overlap Network (larger labels indicate more publications with that designation)

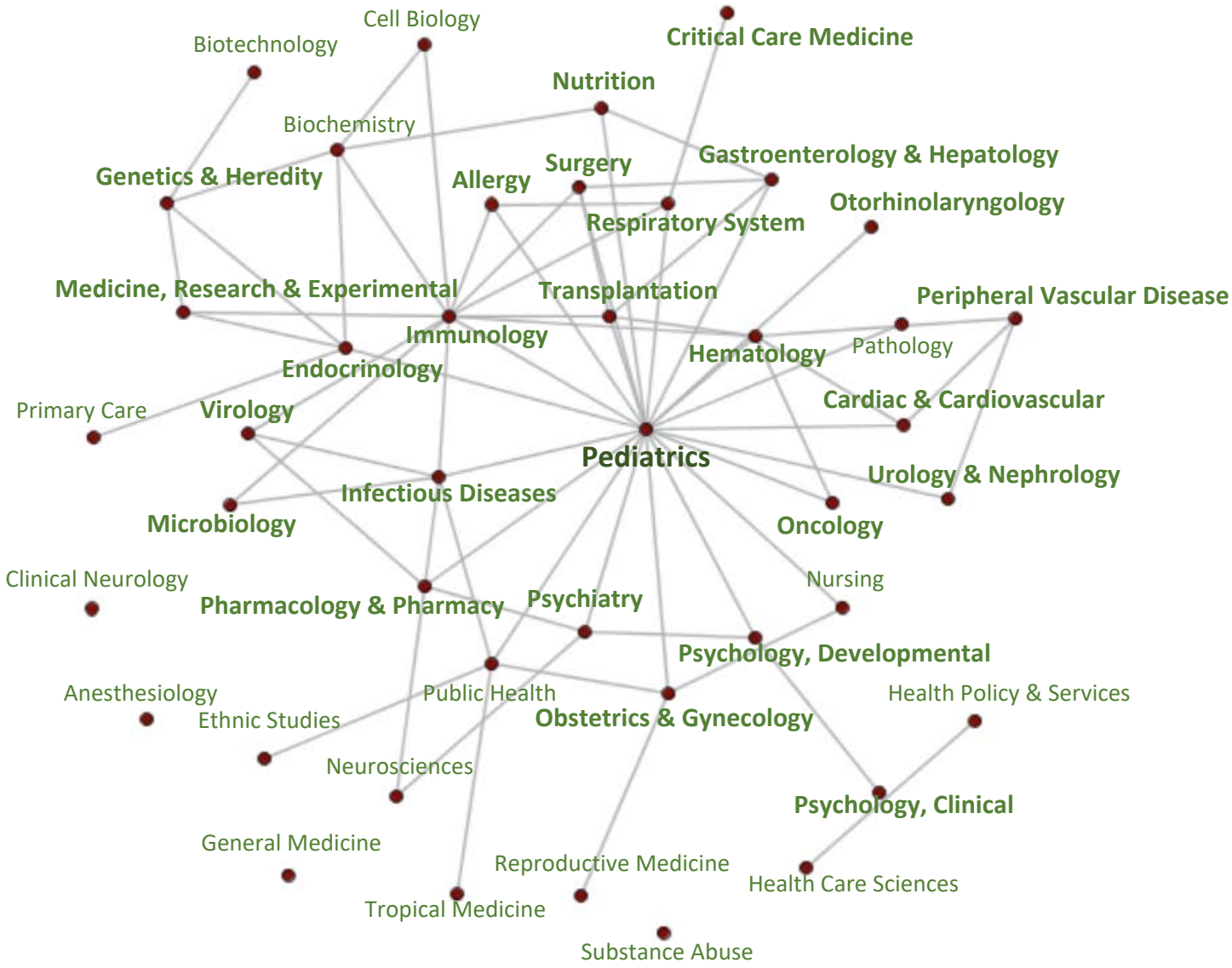
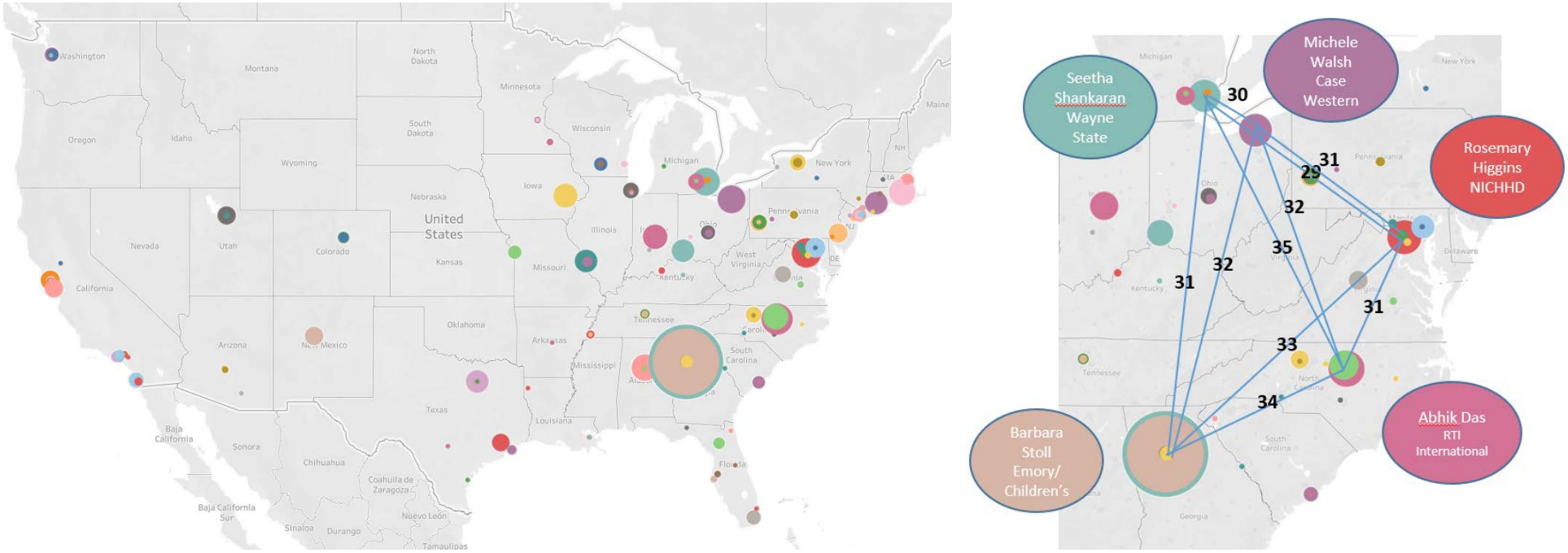
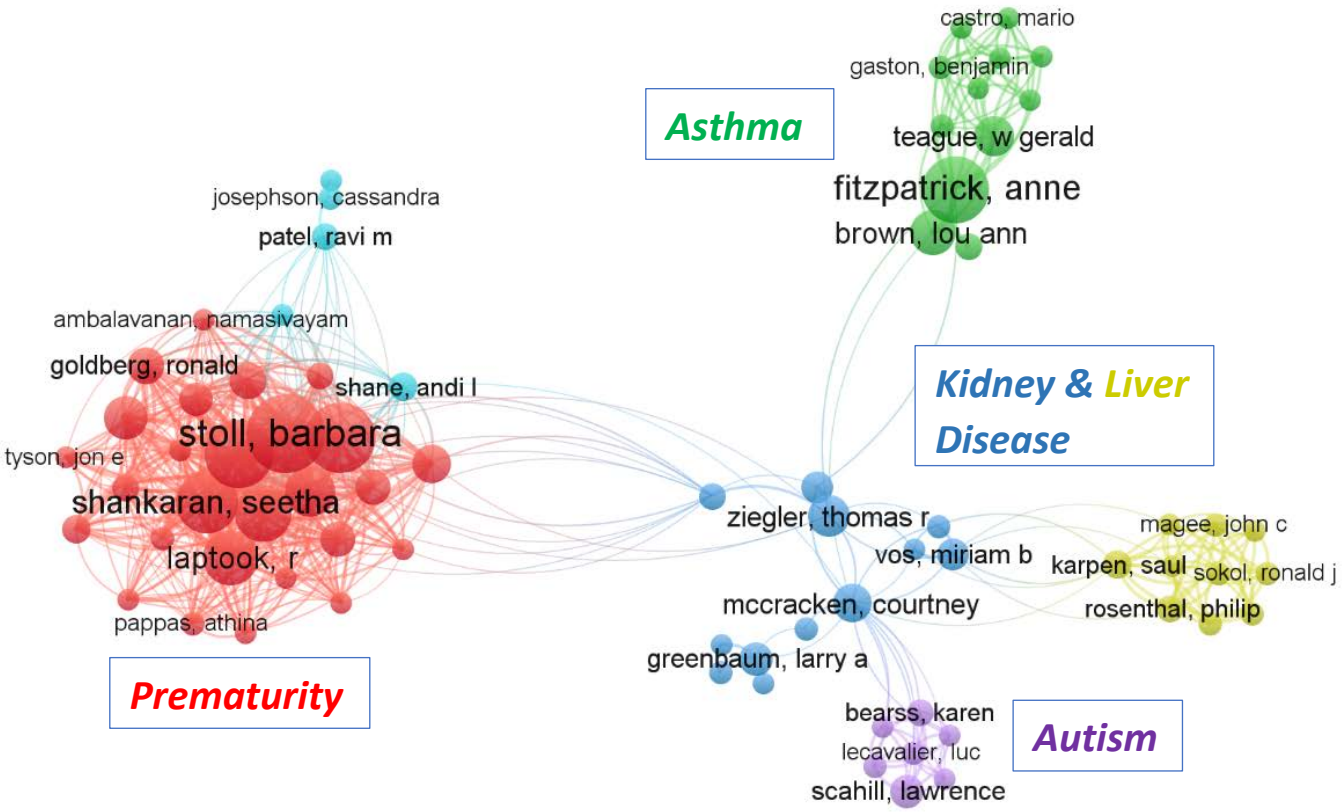


Figure 2. Collaborative Networks

a. Author Institutions Across the US, and Example Co-authorship Network (larger circles indicate more publications from authors at that location)



b. Network of Co-author Collaborative Research Area Clusters



Part 2. Big Splashes and Ripple Effects: Short- and Long-term Impact

The short-term impact of this portfolio is suggested by academic measures that reflect early scholarly interest and readership, and heighten potential for future citations, including publication in high-impact journals, official faculty recommendations, and reader downloads on the Mendeley Reference Management program. This portfolio had a relatively high mean JIF of 8, and maximum JIF of 75 [20], articles were recommended by prestigious Faculty of 1000 (F1000Prime) members 19 times, and articles were downloaded a total of 15,266 times by Mendeley users around the globe. In addition, early public interest in the research is indicated by altmetric attention metrics. The overall average AAS for this portfolio was 26 and the maximum was 677 (for reference, the mean score for the Georgia CTSA portfolio of 2,941 articles was 13 and the maximum is 654). Of the 250 articles, 174 had some form of altmetric attention, and the sum total of AAS scores across these was 5,228, an indicator of the aggregate attention garnered by this portfolio. Relevant components of the AAS for short-term impact included 365 news stories (from sources such as Physician's Briefing, MedicalXpress, and EurekAlert), 73 blog posts (from blogs such as Neonatal Research, Latest BMJ blogs, and JAMA Author Interviews), and 4,494 Twitter posts (largely from science and medical professionals and organizations) to over 17 million followers around the globe.

The long-term impact of this portfolio is demonstrated by high absolute and relative rates of academic citations over time. Articles were cited a combined total of 10,819 times (32% in the past two years), with a mean of 43 citations per article and maximum of 1,091 citations for one article. The mean RCR value was 3.3, or more than 3 times the expected number of citations, and the maximum RCR was 107. Long-term, downstream influence is also indicated by relevant AAS components, including references in 4 Wikipedia articles (for Sepsis, Adrenarche, Sweetened beverage, and one for a study author), 16 filed patent applications (15 of which have been granted), and 33 government policy documents from agencies such as the World Health Organization, the Centers for Disease Control & Prevention, and international health agencies. In addition to patent references, a patent for Respiratory Syncytial Virus (RSV) Expression Vectors (US 10,227,569) was filed by pediatric inventors Martin Moore and Anne Hotard through Emory University and Children's Healthcare of Atlanta in 2012 and granted in 2019. This patent was supported by the Georgia CTSA's UL1RR025008 grant and consists of a plasmid-based expression system for generating the RSV virus to produce new vaccines and drug screening. Investigator Moore was awarded $30,000 in URC/ACTSI pilot grant funding in 2009 to carry out this initial research project, "Respiratory Syncytial Virus Strains: Impact on Disease and Immunity", which allowed his research team to generate preliminary data that later supported acquisition of an R01 grant, a U19 grant, and a publication.

See Table 2 for a summary of metrics that reflect splashes and ripples effects.

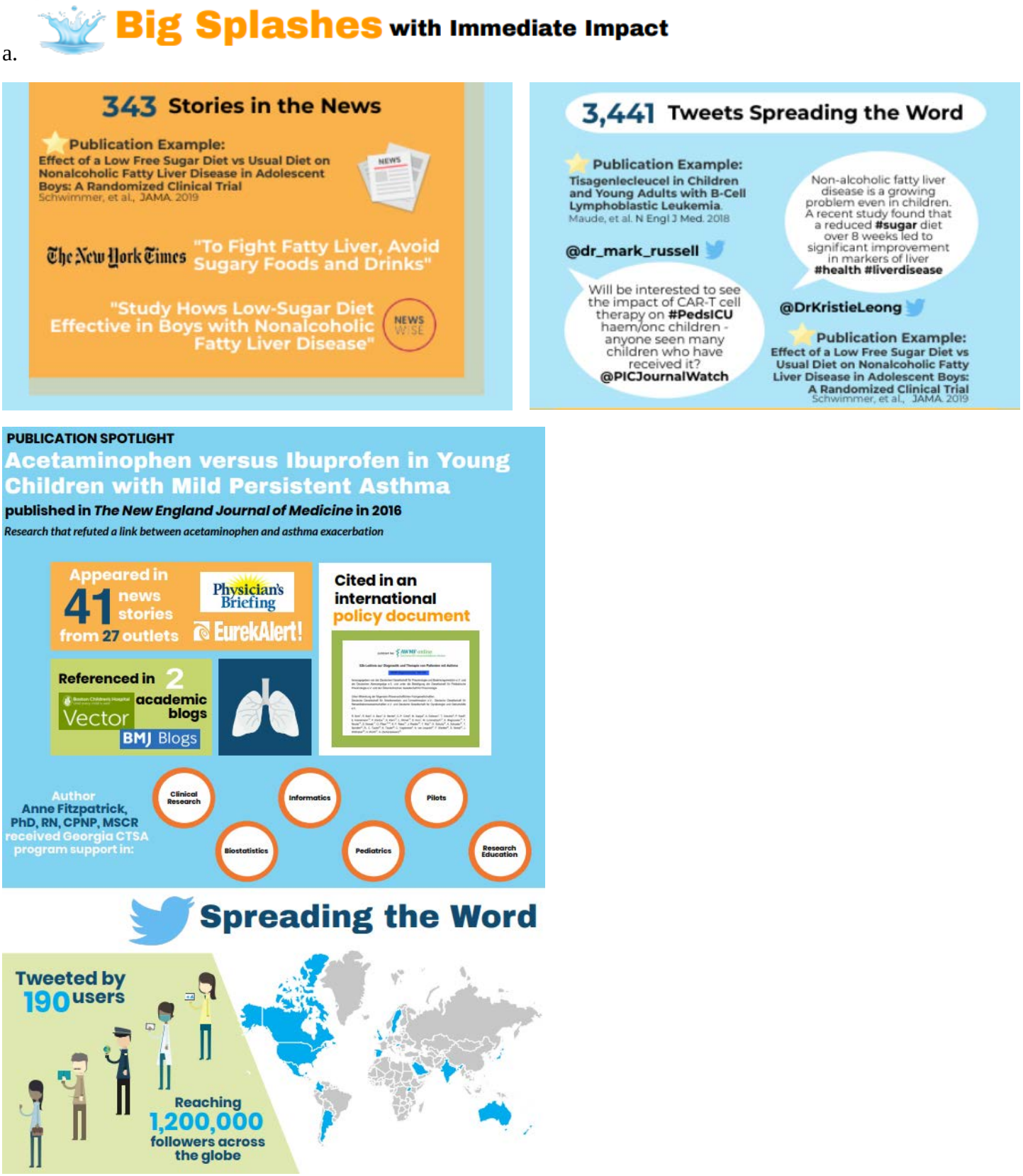
Next, we identified specific publications that represented strong case examples of big splashes and ripple effects. Illustrations of big splashes include: a 2019 article on adolescent fatty liver disease [21] that appeared in the New York Times and 600 tweets to over 2 million followers; and a 2018 article on T-cell therapy for leukemia [22] that appeared in 8 science blogs, and news outlets around the world (e.g. BBC News, Deutsches Arzteblatt, MedIndia). Illustrations of ripple effects include: a 2011 article on sugar consumption [23] that was cited in multiple CDC policy reports; and a 2012 article on a new treatment for kidney disease [24] that led to patents on its formulation and manufacture. See Figure 3 for infographic representations of the impact of these cases and two other examples of significant overall altmetric attention [25,26].

Table 2. Short- and Long-term Impact Metrics & Altmetrics

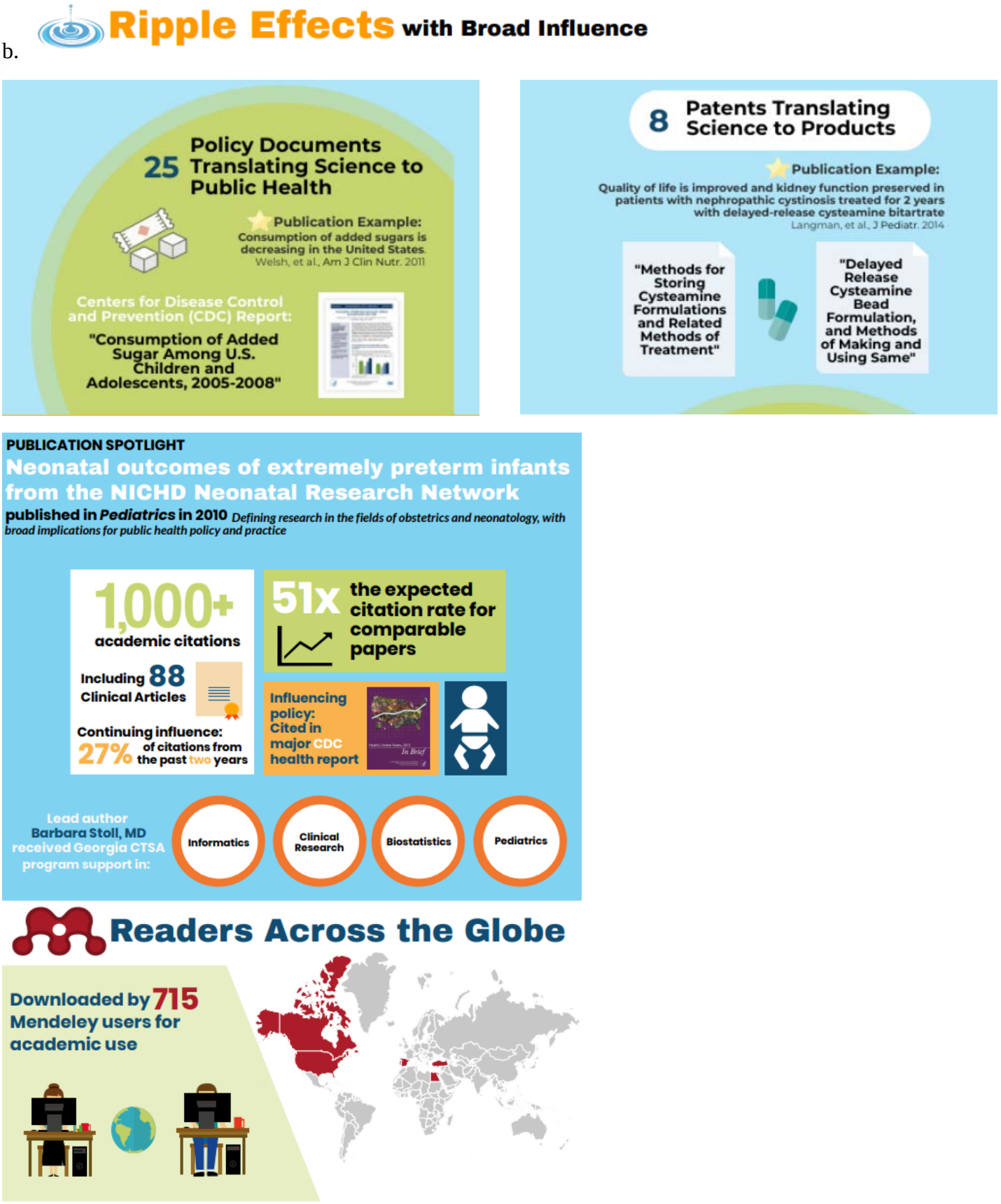
	Mean	***Max***	***Sum***
Short-term Impact Metrics			
Journal Impact Factor (JIF)	8	75	
F1000 Prime Recommendations			19
Mendeley downloads	75	1,029	15,266
Altmetric references in:			
News stories			365
Blog posts			73
Twitter posts			4,494
Long-term Impact Metrics			
Academic citations	43	1,091	10,819
Relative Citation Ratio (RCR)	3.3	107	
Altmetric references in:			
Wikipedia pages			4
Patent applications			16
Policy documents			33

Figure 3. Infographic Case Example Illustrations

a.



b.


Ripple Effects with Broad Influence
25 Policy Documents Translating Science to Public Health
Publication Example:
Consumption of added sugars is decreasing in the United States.
Welsh, et al., Am J Clin Nutr. 2011
Centers for Disease Control and Prevention (CDC) Report:
"Consumption of Added Sugar Among U.S. Children and Adolescents, 2005-2008"
8 Patents Translating Science to Products
Publication Example:
Quality of life is improved and kidney function preserved in patients with nephropathic cystinosis treated for 2 years with delayed-release cysteamine bitartrate
Langman, et al., J Pediatr. 2014
"Methods for Storing Cysteamine Formulations and Related Methods of Treatment"
"Delayed Release Cysteamine Bead Formulation, and Methods of Making and Using Same"
PUBLICATION SPOTLIGHT
Neonatal outcomes of extremely preterm infants from the NICHD Neonatal Research Network
published in Pediatrics in 2010 Defining research in the fields of obstetrics and neonatology, with broad implications for public health policy and practice
1,000+ academic citations
Including 88 Clinical Articles
Continuing influence: 27% of citations from the past two years
51x the expected citation rate for comparable papers
Influencing policy: Cited in major CDC health report
Lead author Barbara Stoll, MD received Georgia CTSA program support in:
Informatics
Clinical Research
Biostatistics
Pediatrics
Readers Across the Globe
Downloaded by 715 Mendeley users for academic use

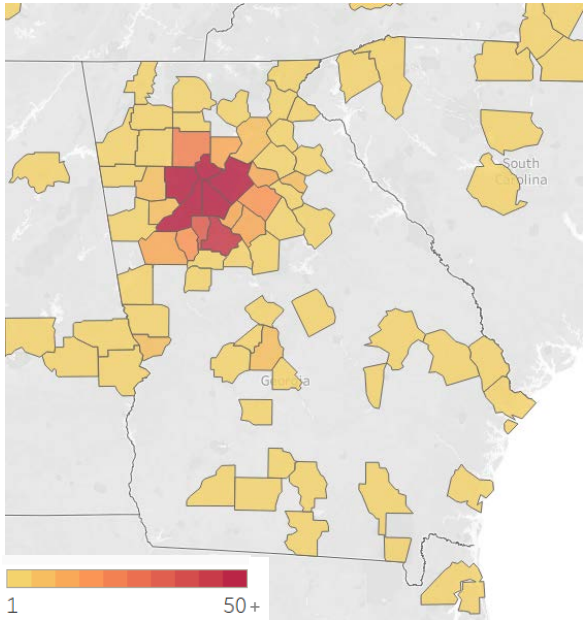
Part 3. Statewide Reach: Impact Across Georgia

The Georgia CTSA has supported pediatric research with participants from hometowns across Georgia and even across the nation. Approximately 5,000 pediatric research participants hailed from at least 5 countries, 38 states, 106 of 159 Georgia counties, and 349 of 953 Georgia zip codes (not all participants could be fully disambiguated due to similar and incomplete identifying information, e.g. names and birthdates). Figure 4 shows the cumulative growth in statewide reach over time, depicting counties from which participants came during the time intervals indicated and including a heat density overlay showing the number of participants from each county. As of 2020, participant representation has gradually increased across the state, such that two thirds of counties are thus far represented, with 78% of visits including participants coming from the five counties that largely encompass the urban Atlanta metro area (Dekalb, Fulton, Gwinnett, Cobb & Clayton counties).

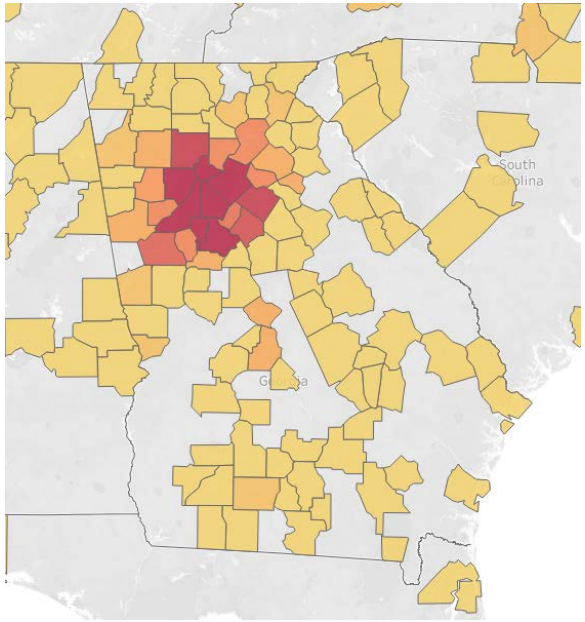
Participants contributed to 175 different studies across diverse fields of pediatric research, the most frequent of which were: **Infectious Disease** (e.g. flu & RSV), **Pulmonology** (e.g. asthma & cystic fibrosis), **Psychiatry** (e.g. depression & PTSD), **Nephrology** (e.g. polycystic kidney disease) & **Endocrinology** (e.g. diabetes). Table 3 and Figure 5 detail the total numbers of participants from the most frequently represented research areas (those with greater than 250 participants) and their distributions across urban and rural areas of the state. There is notable variability in statewide reach and distribution of participants for different areas of research. For example, similar numbers of people participated in psychiatry and nephrology studies. However, psychiatry participants came from few counties and largely from the urban Atlanta metro area, whereas nephrology participants came from many counties and largely from outside the urban Atlanta metro area (including out of state).

Figure 4. Pediatric Research Participants' Home Counties: Cumulative growth in geographic representation over time

a. 2007-2011, 61 counties, 82% from urban Atlanta metro counties



b. 2007-2015, 95 counties, 80% from urban Atlanta metro counties



c. 2007-2020, 106 counties, 78% from urban Atlanta metro counties

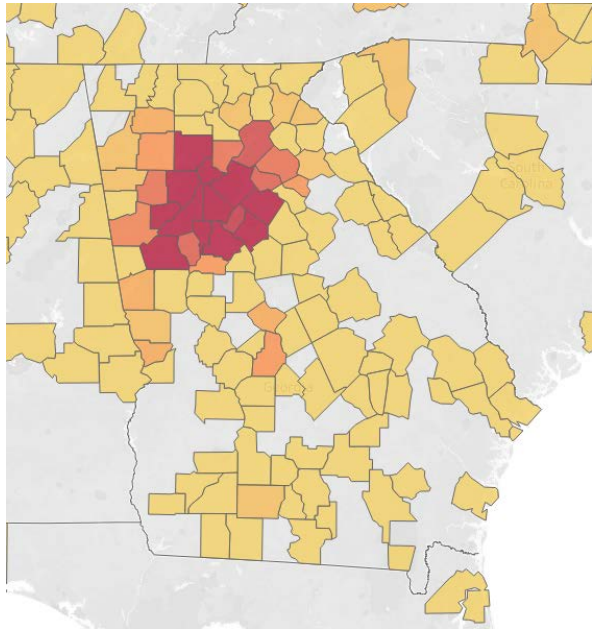
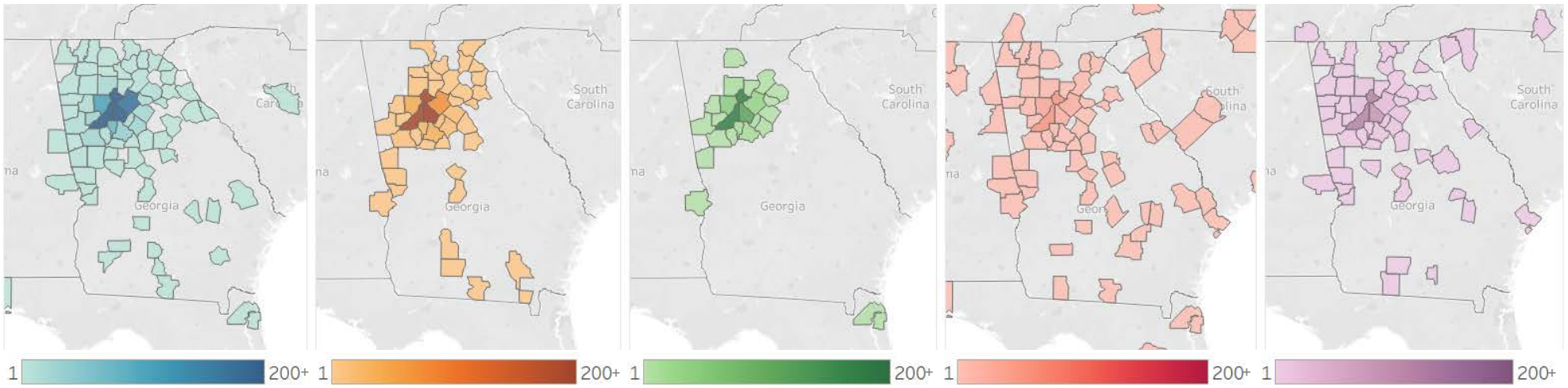


Table 3. Study Participants Across Georgia & Across Research Areas

Research areas with >250 participants	***Total # Participants***	***From # Counties***	***Percentage from urban Atlanta metro counties*** *(Dekalb, Fulton, Gwinnett, Cobb, & Clayton)*
Infectious Diseases	**2293**	80	84%
Influenza	548		
RSV	436		
Pneumonia	199		
Rotavirus	198		
Pulmonology	**817**	51	79%
Asthma	544		
Cystic Fibrosis	171		
Psychiatry	**437**	26	86%
Depression	170		
PTSD	162		
Nephrology	**395**	139	32%
Polycystic Kidney Disease	329		
Endocrinology	**390**	58	66%
Diabetes	312		

Figure 5. Study Participants Depicted Across Georgia & Across Research Areas

a. Infectious Disease b. Pulmonology c. Psychiatry d. Nephrology e. Endocrinology



Conclusions

The purpose of this evaluation was to systematically evaluate the impact of the Georgia CTSA Pediatrics Program through the products that have emerged from supported research between 2007 and 2020. This evaluation delivers a comprehensive and nuanced understanding of the research scope and collaborative patterns of supported pediatric research; the short- and long-term impact of the supported research through cutting-edge bibliometrics, including altmetric methods; and the statewide reach of the program through participant geospatial mapping.

Summary of Part 1. The Big Picture: Research Scope and Collaboration

In the first part of this evaluation we characterized the general content of this pediatric research portfolio by detailing the scope of the research with regard to the translational spectrum from bench to bedside, and by enumerating the journals outlets and research areas in which the research was most frequently published. We further elucidated the interdisciplinary and collaborative structure of the research by reporting on networks of research area and funding source overlap as well as co-authorship. Part 1 demonstrated that the portfolio of publication products that resulted from Pediatrics program support has been diverse in terms of translational phases, journals, research areas, and have been considerably collaborative and interdisciplinary. Supported authors collaborated broadly to advance knowledge in areas from cellular/molecular underpinnings of pediatric diseases to better treatments and practices for childhood illnesses to broad public health concerns affecting pediatric populations.

Summary of Part 2. Short- and Long-term Impact: Big Splashes and Ripple Effects

In the second part of this evaluation we assessed indices of both short- and long-term impact including research that can be described as having made an enthusiastic splash or having had lingering ripple effects in academic and community circles. We utilized both established academic citation metrics and state of the art altmetrics to describe the overall portfolio and to identify some of the most impactful articles in the portfolio. Part 2 revealed that publications supported by the Pediatrics program have made waves throughout both scholarly and community forums. In the near-term, articles showed early potential through publication in well-cited journals, recommendations from highly regarded faculty peers, and downloads of the articles to be read and possibly used downstream. Publications influenced public awareness and discourse when results were covered in local, national, and international news outlets, discussed in health and science-related blogs, and spread through Tweets from health professionals, organizations, and private individuals. In the longer-term, publications demonstrated sustained interest and impact through accumulation of academic citations, even long after publication, contribution to public understanding of science via widely read Wikipedia articles, and translation of research findings to technological advancement (patents) and public health policy (policy documents). Taken together, these findings establish the myriad ways that this research has engendered progress across diverse segments of pediatric medicine. Case examples further illustrate specific areas of notable influence.

Summary of Part 3. Statewide Reach: Impact Across Georgia

In the third part of this evaluation we examined the statewide scope of pediatric research supported by the CTSA by mapping participant home locations across Georgia over time. Part 3 showed that pediatric research supported by the Georgia CTSA has included significant numbers of participants from across the state of Georgia and even beyond. Despite the fact that the GCRCs are centrally located in Atlanta (and later also Athens), research participants came from hometowns at significant distances in suburban and rural Georgia, with the geographic spread increasing over time. Research participants contributed to 175 different studies across many fields of pediatric research, most frequently: Infectious Disease, Pulmonology, Psychiatry, Nephrology & Endocrinology. Fields of research varied significantly in the extent of statewide reach, including proportion of participants coming from urban metro Atlanta.

Limitations & Future Directions

One limitation of our bibliometric methods is that some supported research may be missed. Not all supported researchers will have voluntarily cited the Georgia CTSA grant when publishing their research, and even when the grant is cited, it is not always clear what and how much support led to this research. The Georgia CTSA, and the Pediatrics program, in particular, provides broad-ranging support to investigators that can be minor, major, or accumulating. Currently tracked data does not include detailed information on how support led to a given publication, but this type of tracking could be enhanced in the future, both retrospectively and prospectively.

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

Strengths of this evaluation include novel methods and comprehensive perspectives which speak to the impact of this pediatric research across disciplines, across time, and across Georgia. This highly descriptive report can serve as a starting point for understanding the underpinnings of and associations with the observed trends in pediatric research impact.

Conclusion

In sum, the findings of this evaluation demonstrate the considerable impact of research supported by the Georgia CTSA Pediatrics program. We found a breadth of interdisciplinary research content addressed over the past 13 years, as well as several focused areas of research. The short-term splashes and long-term ripples depicted by both academic metrics and Altmetrics tell the story of the pediatrics program’s research impact in ways that go further than traditional citation measures and inform our understanding of how these research products are being used and translated in both the academic and broader community.

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Appendix 1. Pediatric Publications Included in Bibliometric Analysis

Pubmed ID	Title	Journal. Year
18971491	Aggressive vs. conservative phototherapy for infants with extremely low birth weight.	N Engl J Med. 2008
18417198	Alveolar macrophage phagocytosis is impaired in children with poorly controlled asthma.	J Allergy Clin Immunol. 2008
18708877	Applications of probiotics for neonatal enteric diseases.	J Perinat Neonatal Nurs. 2008
18172746	Diagnosis of Fabry disease via analysis of family history.	J Genet Couns. 2008
18655525	Differences in endocrine parameters and psychopathology in girls with premature adrenarche versus on-time adrenarche.	J Pediatr Endocrinol Metab. 2008
18390958	Neurodevelopmental outcome of extremely low birth weight infants with posthemorrhagic hydrocephalus requiring shunt insertion.	Pediatrics. 2008
18180426	Prediction of psychosis in youth at high clinical risk: a multisite longitudinal study in North America.	Arch Gen Psychiatry. 2008
18166401	Prenatal exposure to viral infection and conversion among adolescents at high-risk for psychotic disorders.	Schizophr Res. 2008
18762491	Very low birth weight preterm infants with surgical short bowel syndrome: incidence, morbidity and mortality, and growth outcomes at 18 to 22 months.	Pediatrics. 2008
19130935	Airway glutathione homeostasis is altered in children with severe asthma: evidence for oxidant stress.	J Allergy Clin Immunol. 2009
19615563	Current advances in chronic kidney disease in children: growth, cardiovascular, and neurocognitive risk factors.	Semin Nephrol. 2009
19204058	Impact of postnatal corticosteroid use on neurodevelopment at 18 to 22 months' adjusted age: effects of dose, timing, and risk of bronchopulmonary dysplasia in extremely low birth weight infants.	Pediatrics. 2009
19895987	Levels of nitric oxide oxidation products are increased in the epithelial lining fluid of children with persistent asthma.	J Allergy Clin Immunol. 2009
19117861	Prolonged duration of initial empirical antibiotic treatment is associated with increased rates of necrotizing enterocolitis and death for extremely low birth weight infants.	Pediatrics. 2009
19448199	Transfusion management of trauma patients.	Anesth Analg. 2009
20351012	25-hydroxyvitamin D status of healthy, low-income, minority children in Atlanta, Georgia.	Pediatrics. 2010
20813855	Association between clinical risk factors and progression of chronic kidney disease in children.	Clin J Am Soc Nephrol. 2010
20689836	Breath formate is a marker of airway S-nitrosothiol depletion in severe asthma.	PLoS One. 2010
19755933	Circulating beta chemokine and MMP 9 as markers of oxidative injury in extremely low birth weight infants.	Pediatr Res. 2010
20875309	Clostridium difficile infections among hospitalized children, United States, 1997-2006.	Emerg Infect Dis. 2010
20400915	Copper supplementation in parenteral nutrition of cholestatic infants.	J Pediatr Gastroenterol Nutr. 2010
19890898	HLA alloimmunization is associated with RBC antibodies in multiply transfused patients with sickle cell disease.	Pediatr Blood Cancer. 2010
20799337	Identification of novel FMR1 variants by massively parallel sequencing in developmentally delayed males.	Am J Med Genet A. 2010
20643715	Impact of timing of birth and resident duty-hour restrictions on outcomes for small preterm infants.	Pediatrics. 2010
20442687	Inhibitory effect of breast milk on infectivity of live oral rotavirus vaccines.	Pediatr Infect Dis J. 2010
20876174	Neonatal candidiasis: epidemiology, risk factors, and clinical judgment.	Pediatrics. 2010

20732945	Neonatal outcomes of extremely preterm infants from the NICHD Neonatal Research Network.	Pediatrics. 2010
20497783	Predictive equations underestimate resting energy expenditure in female adolescents with phenylketonuria.	J Am Diet Assoc. 2010
20542294	Seizures in extremely low birth weight infants are associated with adverse outcome.	J Pediatr. 2010
21761006	Severe Asthma in Children: Insights from the National Heart, Lung, and Blood Institute's Severe Asthma Research Program.	Pediatr Allergy Immunol Pulmonol. 2010
21098157	Survival and morbidity outcomes for very low birth weight infants with Down syndrome.	Pediatrics. 2010
20371397	The molecular phenotype of severe asthma in children.	J Allergy Clin Immunol. 2010
20171649	The rate of bloodstream infection is high in infants with short bowel syndrome: relationship with small bowel bacterial overgrowth, enteral feeding, and inflammatory and immune responses.	J Pediatr. 2010
20147474	Zinc and iron deficiency and their interrelations in low-income African American and Hispanic children in Atlanta.	Am J Clin Nutr. 2010
21076375	24 weeks of valganciclovir prophylaxis in children after renal transplantation: a 4-year experience.	Transplantation. 2011
21305356	A cross-sectional study of docosahexaenoic acid status and cognitive outcomes in females of reproductive age with phenylketonuria.	J Inherit Metab Dis. 2011
21671363	A phase I study of zoledronic acid and low-dose cyclophosphamide in recurrent/refractory neuroblastoma: a new approaches to neuroblastoma therapy (NANT) study.	Pediatr Blood Cancer. 2011
22049049	Anemia and Helicobacter pylori seroreactivity in a rural Haitian population.	Am J Trop Med Hyg. 2011
22147379	Association of antenatal corticosteroids with mortality and neurodevelopmental outcomes among infants born at 22 to 25 weeks' gestation.	JAMA. 2011
21940843	Chronic kidney disease and albuminuria in children with sickle cell disease.	Clin J Am Soc Nephrol. 2011
21768450	Complete surgical resection is curative for children with hepatoblastoma with pure fetal histology: a report from the Children's Oncology Group.	J Clin Oncol. 2011
21753067	Consumption of added sugars is decreasing in the United States.	Am J Clin Nutr. 2011
21798559	Cytokines and neurodevelopmental outcomes in extremely low birth weight infants.	J Pediatr. 2011
21572527	Detrimental effects of environmental tobacco smoke in relation to asthma severity.	PLoS One. 2011
21378596	Early nutrition mediates the influence of severity of illness on extremely LBW infants.	Pediatr Res. 2011
21518717	Early onset neonatal sepsis: the burden of group B Streptococcal and E. coli disease continues.	Pediatrics. 2011
20975618	Glutathione oxidation is associated with airway macrophage functional impairment in children with severe asthma.	Pediatr Res. 2011
21195471	Heterogeneity of severe asthma in childhood: confirmation by cluster analysis of children in the National Institutes of Health/National Heart, Lung, and Blood Institute Severe Asthma Research Program.	J Allergy Clin Immunol. 2011
21883917	Islet xenotransplantation using gal-deficient neonatal donors improves engraftment and function.	Am J Transplant. 2011
21655318	Maternal influenza immunization and reduced likelihood of prematurity and small for gestational age births: a retrospective cohort study.	PLoS Med. 2011
21624618	Obesity and asthma: an association modified by age of asthma onset.	J Allergy Clin Immunol. 2011
21669899	Predictive value of an early amplitude integrated electroencephalogram and neurologic examination.	Pediatrics. 2011

21980183	Prevalence and correlates of multiple cardiovascular risk factors in children with chronic kidney disease.	Clin J Am Soc Nephrol. 2011
21211661	Progressive airflow limitation is a feature of children with severe asthma.	J Allergy Clin Immunol. 2011
21310476	Sex dependence of airflow limitation and air trapping in children with severe asthma.	J Allergy Clin Immunol. 2011
21819424	Stillbirth Collaborative Research Network: design, methods and recruitment experience.	Paediatr Perinat Epidemiol. 2011
21524701	Targeted sequencing of the human X chromosome exome.	Genomics. 2011
21030583	The association between abnormal birth history and growth in children with CKD.	Clin J Am Soc Nephrol. 2011
21654548	The burden of invasive early-onset neonatal sepsis in the United States, 2005-2008.	Pediatr Infect Dis J. 2011
21514635	Thiol redox disturbances in children with severe asthma areÂ associated with posttranslational modification of the transcription factor nuclear factor (erythroid-derived 2)-like 2.	J Allergy Clin Immunol. 2011
21986447	Using change in plasma phenylalanine concentrations and ability to liberalize diet to classify responsiveness to tetrahydrobiopterin therapy in patients with phenylketonuria.	Mol Genet Metab. 2011
21145578	Vaccination of patients with mild and severe asthma with a 2009 pandemic H1N1 influenza virus vaccine.	J Allergy Clin Immunol. 2011
22554716	A randomized controlled crossover trial with delayed-release cysteamine bitartrate in nephropathic cystinosis: effectiveness on white blood cell cystine levels and comparison of safety.	Clin J Am Soc Nephrol. 2012
22206775	Airway TGF-Î²1 and oxidant stress in children with severe asthma: association with airflow limitation.	J Allergy Clin Immunol. 2012
22641761	Approach to infants born at 22 to 24 weeks' gestation: relationship to outcomes of more-mature infants.	Pediatrics. 2012
21840538	Bloodstream infections in very low birth weight infants with intestinal failure.	J Pediatr. 2012
23080477	Brain injury following trial of hypothermia for neonatal hypoxic-ischaemic encephalopathy.	Arch Dis Child Fetal Neonatal Ed. 2012
22504098	Candida virulence properties and adverse clinical outcomes in neonatalÂ candidiasis.	J Pediatr. 2012
22544914	Children with NAFLD are more sensitive to the adverse metabolic effects of fructose beverages than children without NAFLD.	J Clin Endocrinol Metab. 2012
22197855	Correlation of vitamin E, uric acid, and diet composition with histologic features of pediatric NAFLD.	J Pediatr Gastroenterol Nutr. 2012
22562288	Cytokine profiles of preterm neonates with fungal and bacterial sepsis.	Pediatr Res. 2012
22130424	Decreased expression of acetaminophen-metabolizing enzymes and glutathione in asthmatic children after acetaminophen exposure.	J Allergy Clin Immunol. 2012
22230097	Do obese children with diabetic ketoacidosis have type 1 or type 2 diabetes?	Prim Care Diabetes. 2012
22891232	Efficacy of fat-soluble vitamin supplementation in infants with biliary atresia.	Pediatrics. 2012
22675614	Elevated circulating angiogenic progenitors and white blood cells are associated with hypoxia-inducible angiogenic growth factors in children with sickle cell disease.	Anemia. 2012
22424952	Empiric antifungal therapy and outcomes in extremely low birth weight infants with invasive candidiasis.	J Pediatr. 2012
22773736	Excess variants in AFF2 detected by massively parallel sequencing of males with autism spectrum disorder.	Hum Mol Genet. 2012
22931188	Food group intake patterns and nutrient intake vary across low-income Hispanic and African American preschool children in Atlanta: a cross sectional study.	Nutr J. 2012

22924607	High dose vitamin D therapy for chronic pain in children and adolescents with sickle cell disease: results of a randomized double blind pilot study.	Br J Haematol. 2012
22854409	Low-calorie sweetener consumption is increasing in the United States.	Am J Clin Nutr. 2012
22527984	Maternal micronutrient status and preterm versus term birth for black and white US women.	Reprod Sci. 2012
22412036	Methicillin-resistant and susceptible Staphylococcus aureus bacteremia and meningitis in preterm infants.	Pediatrics. 2012
22260536	Mycobacterium tuberculosis Infection of the placenta: a study of the early (innate) inflammatory response in two cases.	Pediatr Dev Pathol. 2012
21930284	Outcome of extremely low birth weight infants who received delivery room cardiopulmonary resuscitation.	J Pediatr. 2012
22644414	Outcome of extremely preterm infants (<1,000 g) with congenital heart defects from the National Institute of Child Health and Human Development Neonatal Research Network.	Pediatr Cardiol. 2012
22689874	Outcome trajectories in extremely preterm infants.	Pediatrics. 2012
22144537	Outcomes following candiduria in extremely low birth weight infants.	Clin Infect Dis. 2012
22236557	Outcomes of extremely low birth weight infants with bronchopulmonary dysplasia: impact of the physiologic definition.	Early Hum Dev. 2012
22704695	Plasma BDNF and PDGF-AA levels are associated with high TCD velocity and stroke in children with sickle cell anemia.	Cytokine. 2012
22903006	Portal hypertension in children and young adults with biliary atresia.	J Pediatr Gastroenterol Nutr. 2012
22615884	Residential proximity to a major roadway is associated with features of asthma control in children.	PLoS One. 2012
22325187	Risk factors for post-neonatal intensive care unit discharge mortality among extremely low birth weight infants.	J Pediatr. 2012
22894927	Risk factors for vitamin D deficiency and relationship with cardiac biomarkers, inflammation and immune restoration in HIV-infected youth.	Antivir Ther. 2012
22802432	Safety and immune responses in children after concurrent or sequential 2009 H1N1 and 2009-2010 seasonal trivalent influenza vaccinations.	J Infect Dis. 2012
22249197	Severe asthma in childhood: recent advances in phenotyping and pathogenesis.	Curr Opin Allergy Clin Immunol. 2012
22095547	Severe asthma: lessons learned from the National Heart, Lung, and Blood Institute Severe Asthma Research Program.	Am J Respir Crit Care Med. 2012
22499140	The fetal environment: a critical phase that determines future renal outcomes in autosomal dominant polycystic kidney disease.	Kidney Int. 2012
22841515	Utility of phenylalanine hydroxylase genotype for tetrahydrobiopterin responsiveness classification in patients with phenylketonuria.	Mol Genet Metab. 2012
22986908	What is the optimal first-line agent in children requiring antihypertensive medication?	Curr Hypertens Rep. 2012
23430796	Accuracy of six anthropometric skinfold formulas versus air displacement plethysmography for estimating percent body fat in female adolescents with phenylketonuria.	JIMD Rep. 2013
22684193	Association between blood spot transforming growth factor-Î² and patent ductus arteriosus in extremely low-birth weight infants.	Pediatr Cardiol. 2013
23619115	Cytochrome P450 2D6 polymorphisms and predicted opioid metabolism in African American children with sickle cell disease.	J Pediatr Hematol Oncol. 2013
23508056	Disparities, race/ethnicity and access to pediatric kidney transplantation.	Curr Opin Nephrol Hypertens. 2013
23295144	Early sepsis does not increase the risk of late sepsis in very low birth weight neonates.	J Pediatr. 2013

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