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The growth and evolution of cardiovascular magnetic resonance: a 20-year history of the Society for Cardiovascular Magnetic Resonance (SCMR) annual scientific sessions

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Abstract

Background and purpose: The purpose of this work is to summarize cardiovascular magnetic resonance (CMR) research trends and highlights presented at the annual Society for Cardiovascular Magnetic Resonance (SCMR) scientific sessions over the past 20 years.

Methods: Scientific programs from all SCMR Annual Scientific Sessions from 1998 to 2017 were obtained. SCMR Headquarters also provided data for the number and the country of origin of attendees and the number of accepted abstracts according to type. Data analysis included text analysis (key word extraction) and visualization by 'word clouds' representing the most frequently used words in session titles for 5-year intervals. In addition, session titles were sorted into 17 major subject categories to further evaluate research and clinical CMR trends over time.

Results: Analysis of SCMR annual scientific sessions locations, attendance, and number of accepted abstracts demonstrated substantial growth of CMR research and clinical applications. As an international field of study, significant growth of CMR was documented by a strong increase in SCMR scientific session attendance (> 500%, 270 to 1406 from 1998 to 2017, number of accepted abstracts (> 700%, 98 to 701 from 1998 to 2018) and number of international participants (42–415% increase for participants from Asia, Central and South America, Middle East and Africa in 2004–2017). 'Word clouds' based evaluation of research trends illustrated a shift from early focus on 'MRI technique feasibility' to new established techniques (e.g. late gadolinium enhancement) and their clinical applications and translation (key words 'patient', 'disease') and more recently novel techniques and quantitative CMR imaging (key words 'mapping', 'T1', 'flow', 'function'). Nearly every topic category demonstrated an increase in the number of sessions over the 20-year period with 'Clinical Practice' leading all categories. Our analysis identified three growth areas 'Congenital', 'Clinical Practice', and 'Structure/function/flow'.

Conclusion: The analysis of the SCMR historical archives demonstrates a healthy and internationally active field of study which continues to undergo substantial growth and expansion into new and emerging CMR topics and clinical application areas.

Keywords: SCMR, Archives, History, CMR, Trends, Cardiac, Heart

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Background

On February 3, 2017, the Society for Cardiovascular Magnetic Resonance (SCMR) celebrated its 20th Annual Scientific Sessions in Washington D.C. Over the past 20 years, the field of cardiovascular magnetic resonance (CMR) has witnessed major advancements in data acquisition speed, image quality and development of novel imaging techniques [1–11], application of CMR to a broader range of cardiovascular diseases [12–25], and the incorporation into consensus statements [26–34] and clinical practice guidelines [26, 35–39].

On the direction of the SCMR Executive Committee, the SCMR Science Committee sought to evaluate research trends in CMR by evaluating session titles from SCMR Annual Scientific Sessions Programs over the past 20 years. Our goal was to track the number of abstracts and scientific contributions, analyze the evolution of research trends and hot topics, and identify the changes in main clinical focus areas and application areas over the past 20 years.

Methods

Data acquisition

Scientific programs from all SCMR Annual Scientific Sessions from 1998 to 2017 were obtained from the SCMR Headquarters Office and SCMR members. Digital program files were available for 2000–2017, while programs of the 1998 and 1999 annual scientific sessions were only available in paper form. SCMR Headquarters also provided data for number of attendees, country of origin of attendees (only available for 2004–2017) and number of accepted abstracts according to type (available for 1998–2018): oral, poster, walking poster, e-poster, moderated poster, and pre-conference workshop. In addition, the ratio of attendance / (number of accepted abstracts) was calculated.

Data analysis

Session titles were abstracted from all programs and collated by year. Digital text analysis and visualization was performed using voyant-tools.org. The tool was used to visualize research and clinical trends by creating 'word clouds' representing the most frequently used key words in session titles in 5-year intervals. Common key words found in many session titles such as 'MRI', 'CMR', 'cardiac', and 'MR' were excluded from the analysis. To further evaluate research and clinical CMR trends over time, session titles were analyzed and subsequently manually sorted into 17 major subject categories. Title counts were grouped into four-year time periods: 1998–2001, 2002–2005, 2006–2009, 2010–2013, 2014–2017. The evolution of these major subject categories was sub-divided into "super growth" (an absolute increase of ≥ 8 sessions from the first time period to the last), and "strong growth" (an absolute increase of ≥ 4 sessions from the first time period to the last). In addition, new categories were defined as those that did not have any sessions in the first time period.

Results

SCMR annual scientific sessions 1998–2017: Location, attendance, abstracts

The dynamics and substantial growth of CMR research and applications are reflected in the evolution of SCMR annual scientific sessions locations and duration (Table 1), scientific session title pages from 1998 to 2017 (Fig. 1), and by the overall annual scientific sessions attendees, number of accepted abstracts over the past 20 years, and attendee / accepted abstracts ratio (Table 2 and Figs. 2 and 3). Figure 1 shows side-by-side comparisons of selected title pages of all 20 past SCMR annual scientific sessions. Style and illustrations reflect choices and preferences by the local organizers, scientific program committee, and SCMR board at the time of the annual scientific sessions. Nevertheless, tracking the temporal evolution of CMR images used for each title page provide an illustration of a trend from basic to advanced CMR methods.

Significant growth of CMR research and clinical applications is corroborated by the consistent and strong increase of SCMR scientific session attendance and abstracts which document a > 500% growth in attendance (270 attendees in 1999 to 1406 in 2017) and a > 700% increase in the number of accepted abstracts (98 in 1998 to 701 in 2018). A more detailed breakdown of annual scientific sessions abstracts (oral and poster presentations) according to type is shown in Fig. 3 and illustrates that the growing number of contributions led to the creation of new categories (walking poster, e-poster, moderated poster) in recent years. As expected, a strong and significant relationship exists between the number SCMR annual scientific sessions attendees and abstract submissions (Fig. 3b). Interestingly, the attendance / accepted abstracts ratio varied considerably during early years (range from 1.1 to 4.5) but has stabilized over the past 7 years, ranging between 2.0 and 2.5.

Table 2 shows a detailed breakdown of SCMR annual scientific sessions attendees by country of origin over the past 14 years (2004–2017). There was a steady overall increase in international participation at the SCMR annual scientific sessions if average attendance in early (2004–2010) and more recent

Table 1 SCMR scientific session duration, annual scientific sessions location, and number of annual scientific sessions attendees 1998–2018

	SCMR annual scientific sessions			
Year	Duration [Days]	Location - City	Location - Country	Attendance
1998	3	Atlanta, Georgia	USA	N/A
1999	3	Atlanta, Georgia	USA	270
2000	3	Atlanta, Georgia	USA	291
2001	3	Atlanta, Georgia	USA	515
2002	3	Lake Buena Vista, Florida	USA	704
2003	3	Orlando, Florida	USA	850
2004	3	Barcelona	Spain	678
2005	3	San Francisco, California	USA	940
2006	3	Miami, Florida	USA	824
2007	3	Rome	Italy	879
2008	4	Los Angeles, California	USA	1107
2009	4	Orlando, Florida	USA	1074
2010	4	Phoenix, Arizona	USA	1150
2011	4	Nice	France	1117
2012	4	Orlando, Florida	USA	1258
2013	5	San Francisco, California	USA	1183
2014	4	New Orleans, Louisiana	USA	1226
2015	4	Nice	France	1451
2016	4	Los Angeles, California	USA	1305
2017	4	Washington DC	USA	1406
2018	4	Barcelona	Spain	N/A

DC District of Columbia, *USA* United States of America

(2010–2017) time periods for the available data are compared; 570 to 641 (12% increase) for attendees from the United States and Canada, 315 to 450 for Europe (43% increase), 29 to 41 for Asia (42% increase), 13 to 19 for Central and South America (45% increase), 9 to 17 for Australia and New Zealand (89% increase), and 3 to 15 for Africa and Middle East (415% increase). As expected, SCMR annual scientific sessions held in Europe (2004, 2007, 2011, 2015) were characterized by an increase of European attendees compared to SCMR scientific sessions in the United States (see Table 2).

Research and clinical trends: Key Word Extraction & Word Clouds

Word clouds summarizing the results of key word extraction from SCMR annual scientific sessions titles are shown in Fig. 4. Results represent the most frequently used words in session titles (increase size indicated more frequent use) for four 5-year periods. Comparison of the temporal evolution of the word clouds over the past 20 years illustrates a topical shift from 'CMR centric' to 'disease centric'. Initially, in years 1–5 (Fig. 4a) CMR techniques and their feasibility, the exploration of different application areas, and questions related to reimbursement were at the center of the SCMR annual scientific sessions. Subsequently, prominent key words such as 'ischemic' and 'enhancement' document the increasing importance of late gadolinium enhancement (Fig. 4b and c). In the past 10 years (Fig. 4c and d), the focus has shifted to clinical applications and translation (key words 'patient', 'disease', 'congenital', are more central). Finally, during the last 5 years (Fig. 4d), the corresponding word cloud reveals a renewed interest in novel techniques and quantitative CMR imaging techniques (more apparent role of key words 'mapping', 'T1', 'flow', 'function').

CMR research trends and highlights at SCMR scientific sessions over the past 20 Years

The number of sessions within all major subject categories over the past 20 years are depicted in Fig. 5a. Between the first time period (1998–2001) and the last (2014–2017), there was an increase in the number of sessions for every category except

Fig. 1 SCMR scientific sessions title pages from 1998 to 2017 illustrating a trend from basic to advanced CMR methods

metabolism. The subject categories Clinical Practice, Congenital, Imaging Techniques, Heart Failure/Cardiomyopathy, and Structure/Function/Flow demonstrated "super growth" (Fig. 5b). The largest increase was seen in Congenital. Clinical practice had the most sessions in four of the five time periods. This category included sessions focusing on clinical cases, career development, global CMR, efficiency, safety, and cost. The category Structure/Function/Flow which has traditionally few sessions experienced "super growth" in the last time period due to sessions on strain, diastolic function, the right ventricle, and 4D flow. The subject categories Ischemic Heart Disease, Clinical Trials/Outcomes, Coronary/Vascular, and Basic/Translational demonstrated "strong growth" (Fig. 5c).

New categories (those that did not have any sessions in the first time period) include Electrophysiology, Tissue Characterization, Analysis/Post-processing, Interventional, and Clinical Application to Special Groups (Fig. 5d). This last category includes titles such as "Phenotyping and Risk Stratification in Hypertrophic Cardiomyopathy", "Assessing the Hematology/Oncology Patient", and "Cardiovascular Disease in Women – CMR's Essential Role".

Case sessions also saw significant growth in number and sophistication. From 1998 to 2001 there was a single case session offered, "Clinical Case Review Session: Bring Your Own". From 2014 to 2017, there were 39 case sessions offered, including a live interventional CMR heart catheterization case presented by Children's National Medical Center at the most recent SCMR annual scientific sessions in 2017. The first SCMR live case (real-time CMR-guided cardiac catheterization in an atrial septal defect patient) was a unique experience for the SCMR audience and a milestone in the history of the SCMR annual scientific sessions. SCMR attendees were provided with the opportunity to watch a clinical CMR catheterization program live in operation and recognize potential benefits of interventional CMR for pediatric and adult patients.

Table 2 Number of attendees of SCMR scientific session by country of origin

	2004 Barcelona	2005 SF	2006 Miami	2007 Rome	2008 LA	2009 Orlando	2010 Phoenix	2011 Nice	2012 Orlando	2013 SF	2014 New Orl.	2015 Nice	2016 LA	2017 Wash DC	Average 2004–2017	Average I 2004–2010	Average II 2011–2017	Change [%] II vs. I
Country																		
United States	371	653	509	314	690	635	513	297	575	606	634	344	806	720	**547.6**	526.4	568.9	**8**
United Kingdom	72	49	49	100	86	83	84	170	114	164	124	299	105	143	**117.3**	74.7	159.9	**114**
Germany	82	81	50	129	103	67	58	122	59	77	58	151	74	64	**83.9**	81.4	86.4	**6**
Canada	9	24	34	38	82	69	52	45	75	93	77	50	75	90	**58.1**	44.0	72.1	**64**
Netherlands	57	29	15	71	50	55	36	102	38	40	44	108	30	45	**51.4**	44.7	58.1	**30**
Sweden	23	18	14	32	26	13	23	33	32	31	26	42	30	39	**27.3**	21.3	33.3	**56**
Switzerland	28	8	13	27	22	15	10	42	24	21	23	55	19	16	**23.1**	17.6	28.6	**63**
France	22	10	6	13	4	8	8	48	14	12	18	57	15	27	**18.7**	10.1	27.3	**169**
Japan	7	14	10	18	22	29	21	15	15	20	12	20	21	16	**17.1**	17.3	17.0	**−2**
Italy	14	9	8	47	10	12	7	38	7	9	0	31	15	12	**15.6**	15.3	16.0	**5**
Australia/NZ	14	5	4	13	12	5	10	24	15	21	8	28	12	11	**13.0**	9.0	17.0	**89**
Brazil/Colombia/ Chile/Argentina	11	5	11	8	8	14	5	14	21	14	8	19	16	22	**12.6**	8.9	16.3	**84**
Spain	75	4	6	17	3	1	2	8	2	2	3	16	3	1	**10.2**	15.4	5.0	**− 68**
Belgium	17	7	5	20	4	4	3	15	1	4	2	18	1	3	**7.4**	8.6	6.3	**−27**
China/Hong Kong	4	5	0	1	6	3	2	11	2	11	1	10	18	13	**6.2**	3.0	9.4	**214**
South Korea	2	2	5	2	4	9	10	7	3	7	6	15	10	4	**6.1**	4.9	7.4	**53**
Austria	6	0	4	16	3	3	2	14	0	3	0	12	0	0	**4.5**	4.9	4.1	**−15**
UAE	3	0	0	2	5	0	0	15	2	0	4	24	3	2	**4.3**	1.4	7.1	**400**
Norway	12	3	1	7	6	1	2	4	4	2	2	8	3	2	**4.1**	4.6	3.6	**−22**
Greece	6	0	4	8	4	4	2	8	3	2	3	8	2	2	**4.0**	4.0	4.0	**0**
Portugal	6	0	0	15	2	0	0	14	1	1	2	14	0	0	**3.9**	3.3	4.6	**39**
Mexico	4	3	5	3	10	4	3	2	5	3	3	4	2	3	**3.9**	4.6	3.1	**−31**
Denmark	10	2	0	4	1	1	3	8	2	2	4	6	1	3	**3.4**	3.0	3.7	**24**
Poland	0	1	0	8	0	10	2	15	0	1	0	5	0	0	**3.0**	3.0	3.0	**0**
Singapore/ Malaysia	3	1	1	5	0	1	1	5	1	1	0	10	0	1	**2.1**	1.7	2.6	**50**
Taiwan/Thailand	1	1	0	0	1	3	3	3	2	4	2	3	2	1	**1.9**	1.3	2.4	**89**
Israel	0	2	0	0	0	1	0	6	1	0	0	6	2	6	**1.7**	0.4	3.0	**600**
Hungary	5	0	0	4	2	0	0	4	0	0	0	3	0	2	**1.4**	1.6	1.3	**−18**
Finland	1	0	0	2	0	3	0	5	0	0	0	9	0	0	**1.4**	0.9	2.0	**133**

Table 2 Number of attendees of SCMR scientific session by country of origin *(Continued)*

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average	Average I	Average II	Change [%]
	Barcelona	SF	Miami	Rome	LA	Orlando	Phoenix	Nice	Orlando	SF	New Orl.	Nice	LA	Wash DC	2004–2017	2004–2010	2011–2017	II vs. I
South Africa	0	0	1	0	0	0	0	1	0	2	2	4	2	7	**1.4**	0.1	2.6	**1700**
India	0	0	0	2	3	0	0	0	2	2	1	4	3	2	**1.4**	0.7	2.0	**180**
Ireland	1	0	0	1	0	2	0	2	4	0	0	3	0	2	**1.1**	0.6	1.6	**175**
Turkey	0	1	2	1	2	0	0		0	1	0	2	2	0	**0.8**	0.9	0.8	**−3**
Egypt	0	0	0	0	0	0	0	0	0	1	0	4	1	3	**0.6**	0.0	1.3	**100**
Czech Repulic	0	0	0	0	0	0	0	1	0	0	1	1	0	0	**0.2**	0.0	0.4	**40**
Russia	0	0	0	0	0	0	0	0	1	0	0	2	0	0	**0.2**	0.0	0.4	**40**
Iceland	0	0	0	0	0	0	1	0	0	0	0	1	0	0	**0.1**	0.1	0.1	**0**
Indonesia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**0.1**	0.0	0.1	**10**
Armenia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0.1**	0.0	0.1	**10**
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0.1**	0.0	0.1	**10**
Region																		
United States & Canada	380	677	543	352	772	704	565	342	650	699	711	394	881	810	**605.7**	570.4	641.0	**12**
Europe	437	221	175	521	326	282	243	652	306	371	309	850	298	361	**382.3**	315.0	449.6	**43**
Asia	17	23	16	28	36	45	37	41	25	45	22	62	54	38	**34.9**	28.9	41.0	**42**
Central & South America	15	8	16	11	18	18	8	16	26	17	11	23	18	25	**16.4**	13.4	19.4	**45**
Australia/NZ	14	5	4	13	12	5	10	24	15	21	8	28	12	11	**13.0**	9.0	17.0	**89**
Middle East & Africa	3	3	3	3	7	1	0	22	3	4	6	40	10	18	**8.8**	2.9	14.7	**415**

LA Los Angeles, *NZ* New Zealand, *SF* San Francisco, *UAE* United Arab Emirates

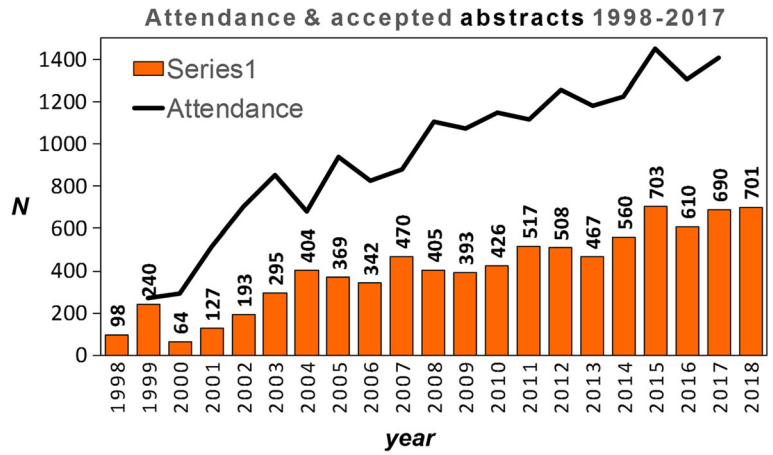

Fig. 2 20-year evolution of SCMR annual scientific session attendance and number of accepted abstracts to be presented at the SCMR scientific sessions. Sustained growths of both annual scientific sessions attendance and scientific contributions are clearly evident. The attendance number of the 2018 meeting were not available at the time of this analysis

Discussion

The results of our analysis of SCMR annual scientific sessions attendance, number and type of abstracts, as well as CMR research and application trends clearly demonstrated a healthy and internationally active field of study which continues to undergo substantial growth and expansion utilizing new and emerging CMR techniques to answer a broadening array of clinical questions. Changes in annual scientific sessions location and annual scientific sessions duration summarized in Table 1 are clear indications of CMR as a growing and international field of study. Initially varying attendees to accepted abstract ratio has stabilized in recent years above 2 indicating a strong and consistent interest in the SCMR annual scientific sessions also for clinicians and scientists who did not submit an abstract. These findings are supported by our key word extraction analysis which

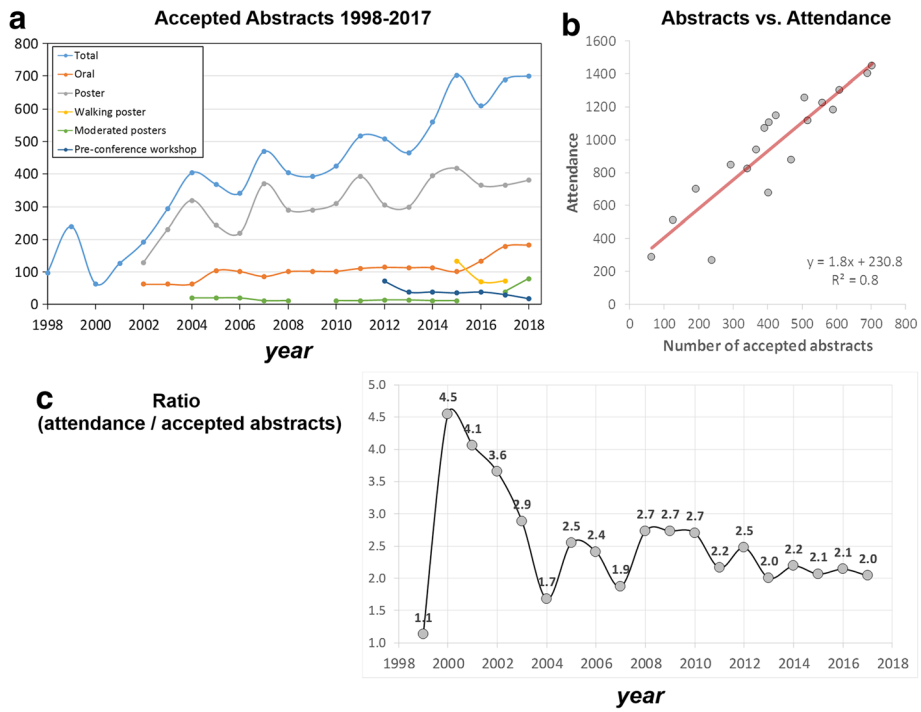

Fig. 3 **a** Changes in number of accepted abstracts by type over the past 20 years. **b** Relationship between number of SCMR annual scientific session attendees and number of accepted abstracts. **c** Development of ratio of attendance vs. accepted abstract over the past 20 years

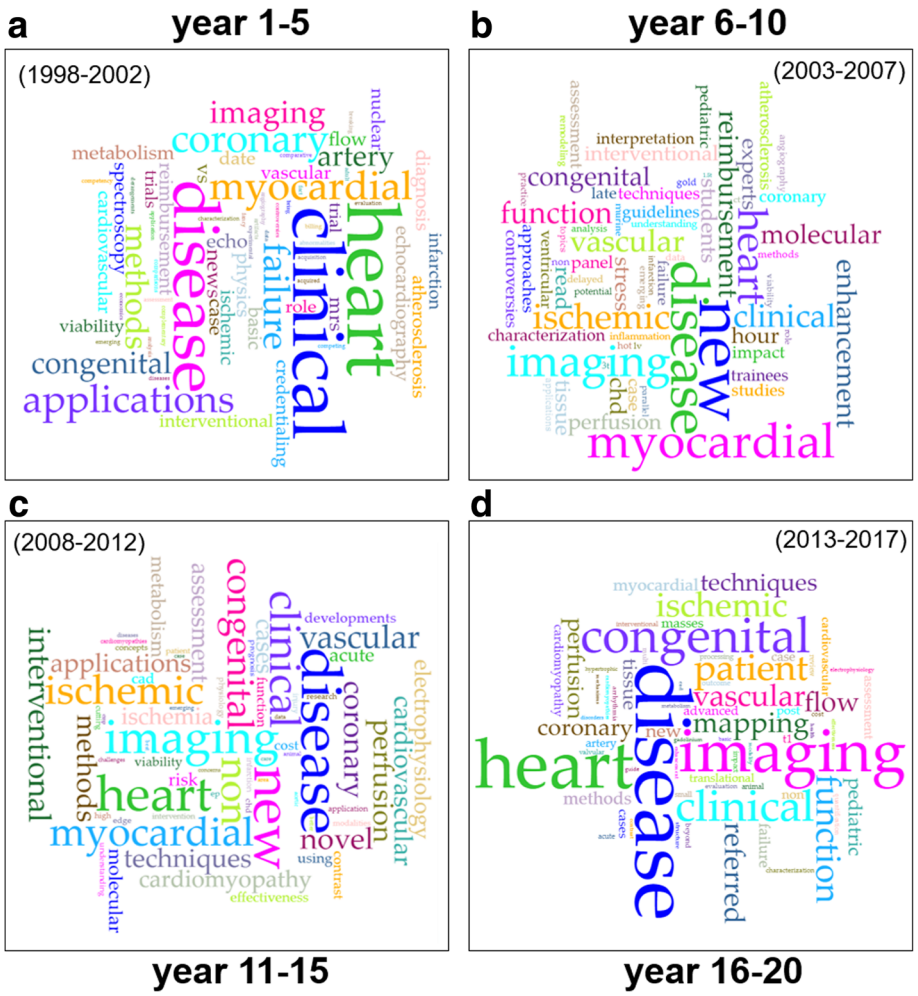

Fig. 4 Word clouds visualizing the frequency of words used in SCMR scientific session titles over the past 20 years. Session titles were grouped in 5-year intervals and represent most frequently used words in SCMR session titles from 1998 to 2002 (**a**), 2003–2007 (**b**), 2008–2012 (**c**), and 2013–2017 (**d**). Word clouds were created using Voyant Tools (http://voyant-tools.org/)

illustrated a shift from early focus on 'MRI techniques and 'feasibility' to patient centered clinical translation and more recently novel techniques and quantitative CMR imaging. These changes were accompanied by a dramatic increase in the number of sessions from 46 in 1998–2001 to 168 in 2014–2017.

Nearly every topic category demonstrated an increase in the number of sessions from the first time period to the last. Clinical Practice led all categories in four of the five time periods. The top three growth areas were Congenital, Clinical Practice, and Structure/function/flow. In many sessions, growth mirrored the development of new imaging techniques or therapies. Tissue characterization has seen substantial growth since mapping techniques have become widely available. The advent of percutaneous valve techniques has coincided with the emergence of sessions dedicated to valve disease. Arrhythmias and CMR used to be mutually exclusive terms, but with real time techniques and recognition of the utility of CMR for defining the substrate for arrhythmias this area has blossomed. The "super growth" in the congenital category is not surprising, given the increasing role of CMR in this growing patient population. The category "Clinical Application to Special Groups" illustrates the growing application of CMR beyond traditional atherosclerotic coronary and vascular disease.

Conclusion

We've seen the programs evolve from very broad sessions with a focus on development and validation, to a wide breadth of sessions that build upon the past and focus increasingly on specific applications to patient scenarios and groups where CMR might

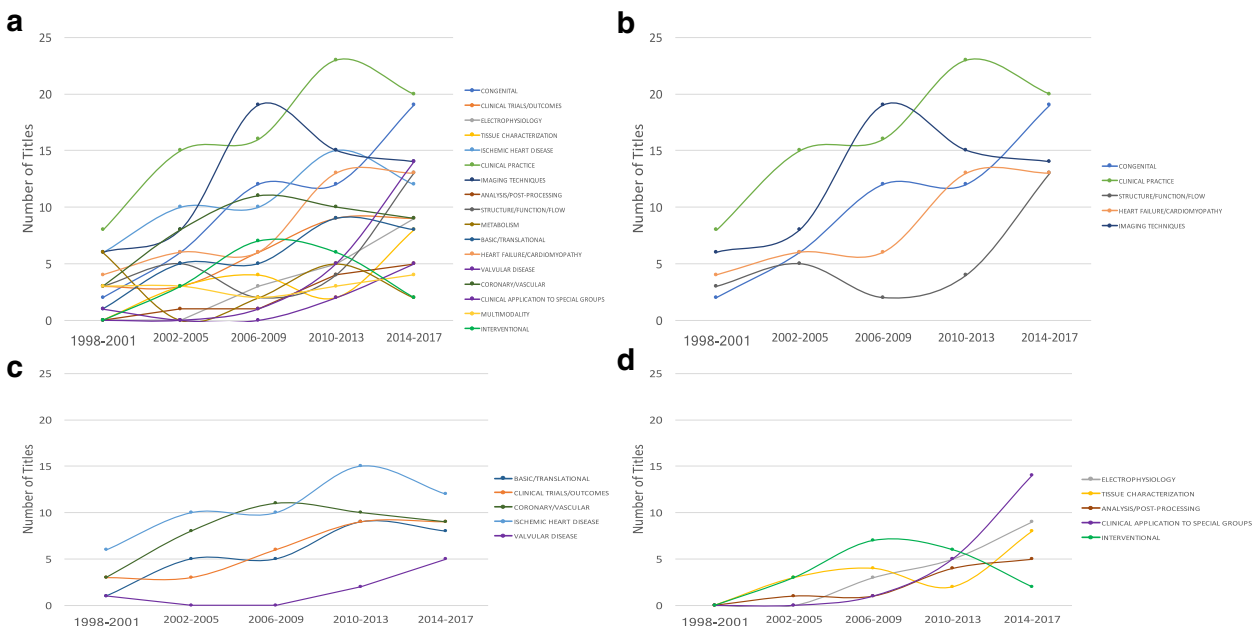

Fig. 5 **a** Number of SCMR scientific session titles within major subject categories - trends over 20 years. **b** SCMR scientific session subject categories demonstrating "Super Growth" – defined as absolute growth ≥ 8 session titles over a 20-year time span. **c** SCMR scientific session subject categories demonstrating "Growth" – defined as absolute growth ≥ 4 session titles over a 20-year time span. **d** Several SCMR scientific session subject categories did not exist in the first time period, but exhibited significant growth in recent years

impact clinical care and practice guidelines. In this context, a continued collaboration between non-clinician PhD scientists and engineers and physician researchers and clinicians coupled with interactions with other clinically oriented societies will be critical for the continued success of CMR. The evolution of sessions at the SCMR annual scientific sessions mirrors the growth and maturation of the science and clinical practice of CMR over the past 20 years.

Abbreviations
CMR: cardiovascular magnetic resonance; SCMR: Society for Cardiovascular Magnetic Resonance

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Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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