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A Quality Assessment of the ARM-Net Registry Design and Data Collection

Isabel C. Hageman [a, b, *], Hendrik J.J. van der Steeg [a], Ekkehart Jenetzky [c, d], Misel Trajanovska [b, e], Sebastian K. King [b, e, f], Ivo de Blaauw [a], Iris A.L.M. van Rooij [g], ARM-Net Consortium[1]

[a] Department of Surgery-Pediatric Surgery, Radboudumc Amalia Children's Hospital, Nijmegen, the Netherlands
[b] Surgical Research, Murdoch Children's Research Institute, Melbourne, Australia
[c] Faculty of Health/School of Medicine, Witten/Herdecke University, Witten, Germany
[d] Department of Child and Adolescent Psychiatry and Psychotherapy, University Medical Center of the Johannes-Gutenberg-University, Mainz, Germany
[e] Department of Paediatrics, University of Melbourne, Melbourne, Australia
[f] Department of Paediatric Surgery, The Royal Children's Hospital, Melbourne, Australia
[g] Department for Health Evidence, Radboudumc, Nijmegen, the Netherlands

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ABSTRACT

Background: Registries are important in rare disease research. The Anorectal Malformation Network (ARM-Net) registry is a well-established European patient registry collecting demographic, clinical, and functional outcome data. We assessed the quality of this registry through review of the structure, data elements, collected data, and user experience.

Material and methods: Design and data elements were assessed for completeness, consistency, usefulness, accuracy, validity, and comparability. An intra- and inter-user variability study was conducted through monitoring and re-registration of patients. User experience was assessed via a questionnaire on registration, design of registry, and satisfaction.

Results: We evaluated 119 data elements, of which 107 were utilized and comprised 42 string and 65 numeric elements. A minority (37.0%) of the 2278 included records had complete data, though this improved to 83.5% when follow-up elements were excluded. Intra-observer variability demonstrated 11.7% incongruence, while inter-observer variability was 14.7%. Users were predominantly pediatric surgeons and typically registered patients within 11–30 min. Users did not experience any significant difficulties with data entry and were generally satisfied with the registry, but preferred more longitudinal data and patient-reported outcomes.

Conclusions: The ARM-Net registry presents one of the largest ARM cohorts. Although its collected data are valuable, they are susceptible to error and user variability. Continuous evaluations are required to maintain relevant and high-quality data and to achieve long-term sustainability. With the recommendations resulting from this study, we call for rare disease patient registries to take example and aim to continuously improve their data quality to enhance the small, but impactful, field of rare disease research.

Level of Evidence: V.

1. Background

Anorectal malformations (ARM) are congenital defects involving the anus and rectum and have an estimated prevalence in Europe of 20–33 per 100,000 live births [1,2]. With the rarity of this disease, data are scarce and scattered. Therefore, patient registries, as information systems that gather clinical data from different health care centers, play a pivotal role in rare disease research [3,4].

Abbreviations: ARM, Anorectal malformations; ARM-Net, Anorectal malformations network; EDC, Electronic data capture; ICD, International classification of diseases; IQR, Interquartile range; OMIM, Online mendelian inheritance in man; ORDO, Orphanet rare disease ontology; PROM, Patient-reported outcome measure; Radboudumc, Radboud University medical center; REDCap, Research electronic data capture.

* Corresponding author. Radboud University Medical Center, Geert Grooteplein Zuid 10, 6500HB Nijmegen, the Netherlands.
E-mail address: isabel.hageman@radboudumc.nl (I.C. Hageman).

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The ARM Network (-Net) Consortium, a group of dedicated European pediatric surgeons, epidemiologists, geneticists, and patient advocacy groups, was established in 2010 [5]. The ARM-Net Consortium has contributed significantly to the field of ARM, with its consensus and publications to harmonize diagnostic classifications, interventional approaches, and psychosocial follow-up [6–8]. Furthermore, it has facilitated ARM patients and their families to provide input and collaborate with clinicians to enhance colorectal care (www.arm-net.eu).

The ARM-Net Consortium also established the ARM-Net patient registry, for which pediatric surgeons identified the data elements to be collected and these were converted and developed into an online interface. Since 2010, this project of dedicated volunteers has successfully registered more than 2200 ARM patients across Europe. The original intention of the registry was to prospectively collect anonymized data on all consecutive patients of the participating centers to surveil epidemiology of ARM and create a screening list of potential subjects for studies in ARM research. However, as the registry developed and grew over the years, it has also served purpose to collect data and conduct research on health-related outcomes for this patient group, including longitudinal data. Several important studies have been conducted with the collected data to improve clinical care for ARM [5,9–15]. Identification of risk factors for unfavorable outcomes, interpretation variation in diagnostics, and different management approaches are amongst the significant contributions resulting from the ARM-Net patient registry.

Although the registry collects valuable information, it has been apparent that not all collected data are useful for documentation purposes, nor directly useable for research. Data cleaning and supplying of missing information are both necessary. Additionally, due to the design of the registry, requested data on individual patients was intentionally limited, as not to discourage surgeons to register their data. As a consequence, potentially relevant information for research purposes is not currently captured in the registry, leading to disparate pieces of information in different places, or unavailability all together. Although these existing hurdles influence the usability and experience with the registry, both from a clinical and a research perspective, the registry has not undergone fundamental changes since its initial setup.

The registry in its current form is very valuable, but it has outgrown its original purpose over its lifetime. Therefore, updates and improvements are warranted for the registry to continue to be of high quality and sustainable for long-term use. For this reason, this study aimed to assess the quality of the ARM-Net registry through analysis of the structure and data elements, collected data, and user experience. More importantly, registries often exhaust their funding on initial setup or engaged investigators may disperse over time, resulting in few resources left for continued maintenance and delivery of high-quality data [4,16]. For this reason, this report aimed to highlight the need for other rare disease patient registries to continuously self-evaluate and adapt to remain relevant, both for clinical and research purposes.

2. Methods

This quality assessment is based on published methods for undertaking quality evaluation of rare disease registries, including assessment of data with the dimensions of quality, monitoring, intra- and inter-user variability studies, requesting and providing feedback and recommendations, and producing a quality evaluation report [4,17–22]. Therefore, the ARM-Net registry quality assessment consisted of three parts: critical analysis of the registry structure and data elements; monitoring of collected data for user variability; and an ARM-Net registry user questionnaire to evaluate user experience. All data were collected in Microsoft Excel 2016 (v16.62, Microsoft Corporation, Redmond, Washington, United States) and, where applicable, analyzed in Stata (v17.0, StataCorp, College Station, Texas, United States).

2.1. Assessment of registry structure and data elements

All 119 data elements in nine categories and accompanying value labels were given a reference number (Supplementary File 1). For each data element and accompanying data of 2287 records, the number of missing data, actions for cleaning, actions for analysis, and suggestions for improvements were recorded as well as assessment of accuracy, completeness, consistency, usefulness, and validity [4,18–22]. Completeness analysis of records was conducted, and completion rate was considered 100% if data was entered for each element. This analysis excluded the automatically created elements (n = 8, as these were never missing), unused elements (n = 4), completion check elements (n = 2), and non-applicable elements if not performed (n = 17, e.g., stoma bowel section if patient has no stoma). The remaining free text string elements for further specifications (n = 24) were also excluded, as these were not mandatory to complete and therefore cannot be regarded as missing data if left blank. A total of 64 elements were included in the completeness analysis. Completeness analysis was also conducted for data elements irrespective of records, meaning completion rate was calculated for each data element and regarded as 100% if there were data for 2287 records. Completeness of one-year follow-up data elements excluded the records of patients whose reconstructive surgery was performed less than one year before date of data extraction from the ARM-Net registry for the current study. Median completion rate for all elements was calculated, excluding the previously specified elements.

2.2. Intra- and inter-user variability

A monitoring session to study intra- and inter-user variability was conducted on ten patients previously registered by a single pediatric surgeon responsible for the registration of patients at the Radboud University Medical Center (Radboudumc). The ten patients were randomly selected based on varying Krickenbeck type [8,23], sex, and age to ensure a sample of patients appropriately reflecting the ARM population. All patients were treated at the Department of Pediatric Surgery at the Radboudumc, with sufficient time since reconstructive surgery, so as one-year follow-up data should be available for both first- and second-time registration. The selected patients were registered by a pediatric surgeon (HJJS) for a second time at least one year after first registration for intra-user variability of the database (User 1A vs. User 1B), and by a second user (junior doctor, ICH), for evaluation of differences between the first and the second user for inter-user variability (User 1 vs. User 2). During second-time registration, User 1 was blinded from their first registration in the ARM-Net registry. For data collection, a copy of the ARM-Net registry was built in Research Electronic Data Capture (REDCap; v12.5.16, Vanderbilt University, Nashville, Tennessee, United States), so as not to affect the existing ARM-Net registry. Certain data elements, such as elements with multiple answers, were coded and exported differently, resulting in a total number 148 data elements per user per patient. Of these 148 elements, five were automatically created by the system and 27 data elements were free text string elements, resulting in 116 data elements included in the analysis. Closed-ended data elements were considered as either congruent or incongruent. Open-ended free text data elements were analyzed for differences in interpretation, which were categorized per subject. The absolute total of discrepancies in the collected data and the number of data

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elements with discrepancies were reported. Differences between intra- and inter-user variations were tested for significance using independent Students' t-tests and considered statistically significant at a p-value of <0.05.

2.3. ARM-net registry user questionnaire

In collaboration with pediatric surgeons (SKK, IdB, HJJS), ARM researchers (MT, IALMvR), and ARM-Net data managers (IALMvR, EJ), the ARM-Net registry user questionnaire was developed and aimed at all ARM-Net users who contribute patients to the registry. It consisted of items on current and future purposes of the registry, maintenance, satisfaction with collected elements and desired changes, ease of use, limitations, and general satisfaction (Supplementary File 2). The questionnaire was built in Castor EDC (v2022.3.0.0, Castor, Amsterdam, The Netherlands) and sent out to all 32 users responsible for data input at their respective centers. Users were given a minimum period of two months, with three reminders, to complete the questionnaire. Percentages of response are presented without decimals, as the total absolute number of users that have completed the questionnaire is less than 100.

3. Results

3.1. Assessment of registry structure and data elements

There were 119 data elements, of which eight were automatically created by the electronic data capturing (EDC) system of the ARM-Net registry. Seven involved time and person creating, modifying, and locking records. One was a unique identifier to anonymize the data and prevent duplicate entries, generated by entering the date of birth of the patient and the year of birth of the patient's mother. Four elements included in the data dictionary were not present in the registry interface and were therefore not used in data collection. Of the remaining 107 utilizable elements, there were 42 string and 65 numeric data elements (Supplementary Table 1). The data elements could be categorized into several groups: automatically created administrative, patient demographics, ARM diagnosis, family history of congenital abnormalities, genetic testing and availability of biosamples, associated anomalies, surgical procedures and associated complications, one-year follow-up data, and completion of the record checks (Table 1). The majority (63.6%) of the 107 utilized data elements were dedicated to associated anomalies and surgery.

Complete data was available for only 37.0% of records. However, when excluding the one-year follow-up data elements (n = 10) completion rate improved to 83.5% (Fig. 1A). Irrespective of record completeness, median completion rate per data element was 99.6% (IQR 99.3–99.6%), with a median completion rate of 58.6% (IQR 51.1–63.3%) for the one-year follow-up data elements only (Fig. 1B) for patients with a reconstruction more than one year before data extraction.

Completeness of data elements does not necessarily equal useful data. For many of the elements, there is the option to select 'Unknown'. For the data elements on family history of congenital malformations in the parents of the patient, 34.4% and 32.3% of records had 'Unknown' answers for father and mother, respectively. The remaining data elements on family history of siblings and extended family members had an even higher proportion, with a median of 72.8% (IQR 72.4–84.5%) of records 'Unknown'. This raises the question of relevancy of these elements when information on extended family members is seemingly often unavailable.

There were 27/107 (25.2%) elements that were free text fields, allowing a user to add an additional description of a previously chosen answer, or when the option 'Other' was selected. For these data elements, there were 61–577 different answers entered per item. From the collected data it was evident that the free text elements are utilized more often than the option 'Other' is selected, presumably because the existing answer options in the corresponding single-choice question were not sufficient or satisfactory. This was especially interesting for the free text element on Krickenbeck classification, which was utilized for 283 records, whilst the answer option 'Other' for the closed-ended Krickenbeck element was only selected for 20 records. Another reason free text elements were used was to register information that could not be collected elsewhere, such as prematurity, birth weight, order of birth, and method of conception.

The majority of single-choice data elements on associated anomalies collected data on whether the respective organ system was 'Abnormal' or 'Normal', whether it was 'Not checked', or whether this information was 'Unknown'. Although these data elements have subsequent free text fields for descriptions, users did not always utilize them. When information was provided in these fields, it often required extensive cleaning and human interpretation.

3.2. Intra- and inter-user variability

Both User 1 and 2 registered 10 patients, entering 116 data elements per patient, totaling 1160 entered datapoints per user. Discrepancies between first- and second-time registration (User 1A and User 1B) for a single user demonstrated that there is intra-user variability, with 11.7% of collected data incongruent. Similarly, the number of discrepancies between User 1 and User 2 showed that there is also inter-user variability, with 14.7% of collected data differing between the users (Table 2). The number of intra-user and inter-user discrepancies were not statistically different (136 vs. 170; $p \geq 0.20$). The discrepancies were found in 61 and 70 of the 116 data elements for intra- and inter-user variability, respectively. To determine which data elements might be specifically sensitive to intra- or inter-user variability, the number of data elements with three or more discrepancies in the 10 patients registered were determined, but the difference in intra- and inter-user variation (15.5% vs. 23.3%, respectively), was not statistically significant.

For intra-user variation, elements with discrepancies were found in the categories of, in order of frequency, associated anomalies (n = 57), surgery and complications (n = 30), family history (n = 17), one-year follow-up (n = 15), genetic testing and biosamples (n = 9), patient demographics (n = 6), and diagnosis (n = 2). The three data elements with the most discrepancies were "Brain abnormality" (n = 10), "Other gastrointestinal abnormality" (n = 8), and "DNA sample" (n = 6). For the first two elements, the discrepancies resulted mostly from 'Normal' chosen at first-time registration, contrary to 'Not checked' chosen at second-time registration. For "DNA sample", discrepancies came from missing data.

Table 1
Overview of number of data elements per category.

Category	Number of data elements
Administrative	8
Demographics	10
ARM diagnosis	2
Family history	10
Genetic testing and biosamples	5
Associated anomalies	49
Surgery and complications	19
Completion check	2
One-year follow-up	12
Not used	*4*
Total	**119**

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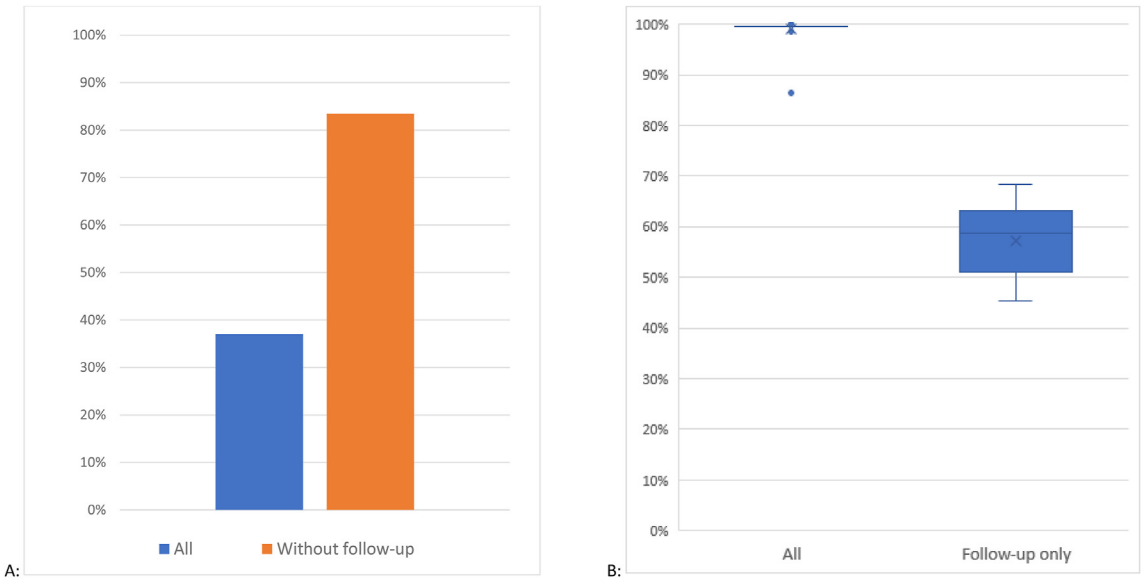

Fig. 1. (A): Proportion of records with complete data for all data elements and without follow-up elements. (B): Median completion rate per data element of all data elements and follow-up data elements only.

Table 2
Intra- and inter-user variation.

	User 1A vs. user 1B Intra-user variation	User 1 vs. user 2 Inter-user variation	*p*-value[b]
Total real discrepancies ($n = 1160$[a])	136 (11.7%)	170 (14.7%)	0.20
Data elements with discrepancies in ≥1 record(s) ($n = 116$)	61 (52.6%)	70 (60.3%)	0.24
Data elements with discrepancies in ≥3 records ($n = 116$)	18 (15.5%)	27 (23.3%)	0.20

[a] 116 data elements per patient, with 10 patients resulting in a total of 1160 datapoints.
[b] Independent Students' t-test to test for significant differences between the variations.

The data elements subject to inter-user variability fell, in order of frequency, into the categories of associated anomalies (n = 101), one-year follow-up (n = 26), surgery and complications (n = 22), genetic testing and biosamples (n = 13), family history (n = 3), diagnosis (n = 3), and patient demographics (n = 2). Similar to the results of intra-user variation, the three data elements with the most discrepancies found were "Other gastrointestinal abnormality" (n = 10), "Spinal canal/cord specification" (n = 8), and "DNA sample" (n = 6). The discrepancies for "Other gastrointestinal abnormality" were mostly because User 1 selected 'Normal', whereas User 2 entered 'Not Checked'. "Spinal canal/cord specification" mostly had discrepancies because the data were missing by the first user, and the same was for "DNA sample". This might be because the original ARM-Net registry has 'Unknown' as the default answer when untouched, contrary to the REDCap version, where there were no default answers and non-selection resulted in missing data.

3.3. ARM-net registry user questionnaire

The ARM-Net registry user questionnaire had a response rate of 75% (24/32) with complete information provided by 23/24 respondents. The results of the questionnaire could be categorized in current and future design of the ARM-Net registry, registration of patients, and satisfaction (Table 3). The initial purpose of the registry was surveillance of all consecutive ARM patients in participating centers. Over a third (38%) of users have indeed selected this as the current purpose, while only 13% believed this is a future purpose of the registry. Most users (54%) believed the current purpose of the registry was for clinical research and would like the future purpose to shift to improving clinical care (71%).

The majority of users wanted to collect patient-recorded outcome measures (PROMs) and to expand the follow-up period, currently at 5 years, to at least until adulthood, up to lifelong. The current registry data element with most votes for removal from the registry was DNA sample, followed by eye/ear abnormalities, family history, and facial dysmorphic features. Of all users, 21% selected 'Other' for removal of an item, which comprised of removal of no data elements (15%), removal of free text option for DNA sample (3%), and removal of the dermatological problems data element (3%). Users were willing to collect more items, with prematurity and birthweight, cardiac abnormality consequences, and expansion of diagnostic tests as frequently chosen. Other data elements users suggested for inclusion were incontinence scales, dilatation regimens, date of stoma placement, menstrual outflow obstruction, methods of conception, and PROM questionnaires on patient/parent satisfaction, quality of life, sexual function, urinary function, and incontinence/constipation. The majority of users made use of the free text fields and supported the need to keep this option to gather specific information, rather than just using an 'Other' option without the availability of specification in a free text field.

Patients were mostly registered by their treating pediatric surgeon (71%) and registration took approximately 11–30 min (61%) for most users. A patient was registered when the pediatric surgeon remembered to do so (61%), and follow-up entry was remembered with a manual note in the patient's medical file (35%). Users were generally satisfied (65%) and found the ARM-Net registry easy to use (65%), rating the registry with an overall mean grade of 7.4 on a

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Table 3
Responses of ARM-Net registry user questionnaire.

Design									
Item	**Answer options and response rate* (%)**								
Current purpose of the registry	Surveillance of all ARM-patients (38%)		Improvement of clinical care (8%)		**Scientific research (54%)**				
Future purpose of the registry	Surveillance of all ARM-patients (13%)		**Improvement of clinical care (71%)**		Scientific research (17%)				
Collection of PROMs	No (22%)				**Yes (78%)**				
Pay a fee for maintenance	**No (65%)**				Yes (35%)				
Expand follow-up period	No (13%)				**Yes (87%)**				
Use of user manual	No, I did not know there was a manual (22%)	**No, I know how to register a patient (35%)**		Yes, only for the first patient (13%)		Yes, occasionally (30%)		Yes, always (0%)	
Helpfulness of user manual	No (13%)			Yes (39%)			**Not applicable (48%)**		
Delete item	Family history (18%)	**DNA sample (27%)**		Throat/lung/thorax abnormalities (15%)		Eye/ear abnormalities (24%)	Facial dysmorphic features (18%)		Other (21%)
Collect more items	No (30%)				**Yes (70%)**				
Add item	Order of birth (6%)	**Prematurity and birth weight (49%)**	Kidney function (eCRF / creatinine) (30%)	Voiding cystourethrogram (36%)	Cystoscopy (27%)	Echocardiogram (21%)	Cardiac abnormality consequences (42%)	Constipation based on Rome IV criteria (33%)	Other (21%)
Use of free text fields	Never (4%)		Rarely (26%)		**Sometimes (65%)**		Always (4%)		

Keeping free text fields	**I would like to keep the "free text" option to know the exact information (78%)**			I am happy to only have the option "other" without an explanation / specification (22%)		
Registration						
Who registers a patient	**Only me (pediatric surgeon) (71%)**	Another colleague (pediatric surgeon, always the same one) (13%)	Other colleagues (pediatric surgeons, different ones) (0%)	Another specialist or nurse, nurse practitioner, research nurse, case manager (4%)	Me and another colleague (13%)	I don't know (0%)
How long does registration take	≤10 minutes (13%)	**11-30 minutes (61%)**		31-60 minutes (22%)	>60 minutes (4%)	
When is a patient registered	Directly after a consultation/visit (0%)		I plan a separate time slot (39%)		**When I remember to do so (61%)**	
How to remember follow-up entry	I don't, I usually forget (22%)	I note a reminder in patient file **(35%)**	I set a reminder in my calendar (13%)	Someone else reminds me (13%)	I don't know (17%)	
Satisfaction						
Satisfaction	Not satisfied (0%)	Somewhat satisfied (30%)		**Satisfied (65%)**	Very satisfied (4%)	
Difficulty	Difficult (4%)	Somewhat difficult (13%)		**Easy (65%)**	Very easy (17%)	
Overall grade (1-10)	**7.4**					

Abbreviations: ARM, anorectal malformation; PROMs, patient-reported outcome measures.

** The answer options presented reflect the possible options provided to the users, with the users' most commonly selected answer in bold.*

scale of 1–10, with 1 being useless and 10 being perfect. Users were largely not willing to pay a yearly fee for maintenance of the registry (65%). Those who would pay entered a fee ranging from 25 to 500 euros a year, with 50 euros as the most common answer.

4. Discussion

The current study evaluated the quality of the ARM-Net registry through a critical analysis of the structure and data elements, the collected data, and the user experience. Most data elements were dedicated to collecting information on associated anomalies and surgery. A quarter of the data elements were free text fields, resulting in a very high number of up to nearly 600 different answers submitted for a single field, varying from further specifications of previous data elements to information that cannot be registered anywhere else in the registry. This suggests that the registry has outgrown its initial purpose and that existing data elements and answer options are not fully satisfactory. Unsatisfactory data elements and answer options result in room for interpretations and frequent use of free text fields, making the registry vulnerable to mistakes and imputation errors. The user experience questionnaire also confirmed this, where the majority of users opted to use free text fields and suggested the addition of several data elements currently missing in the registry.

According to the ARM-Net registry user questionnaire, most users registering patients were pediatric surgeons, but still the registry has apparent tendency for differences in data collection, or intra-user and inter-user variability. Up to 15% of collected data was

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incongruent between users and between different timepoints of registration by a single user. This shows that discrepancies in data collection exist not only between different users, but also equally for the same user. The most common discrepancies were either due to missing data or interpretation differences. Absence of clear documentation in the patient's medical file can either be interpreted as a specific item not checked for or considered as normal. Additionally, irrespective of intra- or inter-user variability, the discrepancies mostly occur in the category of associated anomalies, surgery and complications, and one-year follow-up, indicating that the elements in these categories should be evaluated for improvement to minimize imputation errors or left missing. Several data elements that fall in these categories were also selected by the users in the questionnaire to be removed.

Although implemented after first initiation of the registry due to wishes from the pediatric surgeons, one-year follow-up data entry is still an evident weakness of the registry, with the number of complete records being only 37%, while increasing to over 80% when excluding follow-up data elements. Nevertheless, most users reported that more follow-up data should be collected and preferred to expand the follow-up period to at least until adulthood. Incompleteness of data is clearly an issue and might be explained by the fact that users indicated that patient registration was mostly done when they remembered to do so, and there is no reliable notification to enter follow-up data other than a note in the patient medical file, which, with a completion rate of around 60% per data element, is visibly unreliable and insufficient. Additionally, the limited clinical relevance or predictive value of clinical outcome at one year follow-up presumably limits surgeons to complete the data. Therefore, expanding the follow-up period not only has more clinical relevance, but surgeons may also be more inclined to complete these data.

The user questionnaire aimed to gain an insight on changes that users would like to see and how they experience patient registration, but also to clarify certain incongruencies in the collected data. Both user satisfaction and ease of use were highly regarded by the users. Interestingly, it was apparent that many users preferred the availability of free text elements to continue in the future. However, from a research and data management perspective, free text elements are difficult to analyze and require extensive data cleaning. This demonstrates that there is a discrepancy between what the ARM-Net registry users, mostly pediatric surgeons or otherwise clinical staff, ideally prefer to collect, and what is ideal from a data research perspective. Furthermore, it was also clear that the users would like to move towards a more clinically oriented and patient-centered registry from their preference to remove dysmorphia- and hereditary-related items and start collecting PROMs. Engagement of patients will enhance the registry's scope and longevity, and provide valuable insight into a patient's life [19]. PROMs are paramount to consider when aiming to improve clinical care, in line with the users' preferred future purpose of the ARM-Net registry.

The current study has several limitations. Firstly, the evaluation of the structure of the registry, its data elements, and the collected data was performed based on the available literature, rather than an existing methodology, which has yet to be developed. Considering that patient registries can vary widely in their covered condition, purpose, structure, and lifetime, no single method can encompass all aspects of a registry evaluation. However, the critical analysis in the current study is based on well-recognized components of data quality assessments in patient registries, such as quality dimensions of accuracy, validity, completeness, consistency, usefulness, and prevention of duplicate entries [4,18–22]. A second limitation is that the intra- and inter-user variability study only included two different users, with different levels of training, registering a small sample of 10 patients. Ideally, quality monitoring should be repeated across all participating centers in the different countries, with different pediatric surgeons, and covering a larger patient sample. Nevertheless, the small sample of patients with two users from the same center and identical instructions on patient registration, does not invalidate the findings of variability in the current form of data collection. In order to confirm the degree of variability, evaluation of intra- and inter-user variability is needed on a larger scale across all participating centers.

A third limitation may be the representativeness of the ARM-Net registry user questionnaire. The users who completed the questionnaire were responsible for data collection in large surgical centers and cumulatively registered more than 80% of all records. Therefore, it is unlikely that they are not representative of ARM-Net registry users. Finally, the user questionnaire is not a standardized survey, but rather tailored specifically to the issues data managers experienced with the ARM-Net registry and reviewed by pediatric surgeons, ARM researchers, and ARM-Net data managers, which although not validated, we believe is sufficient for the purpose of this study.

Despite the lack of a systematic quality assessment process for registries, which has yet to be developed, this study has followed the recommendations of evaluation according to quality indicators and dimensions, site monitoring, and a questionnaire [18]. Furthermore, we have conducted several methods previously described on how to conduct a registry quality assessment, including an intra- and inter-user variability study, providing feedback and recommendations, and writing the present data quality report [17]. Therefore, the present quality assessment encompasses all the available methods to evaluate the ARM-Net registry appropriately.

Recommendations for improving the quality of the ARM-Net registry and other rare disease registries.

Three areas of the ARM-Net registry were identified as requiring improvement: 1) structure of data collection, 2) completion of data, and 3) clinical value of data. Firstly, addition and removal of data elements, expansion of answer options, nested further specification items dependent on selected answer options, default answers or error messages when items left blank to prevent missing data, and a reduction of free text fields should be considered. Data collected via free text elements should be evaluated to create additional answer options and elements, as the existing elements and answer options seem not to be satisfactorily sufficient. Data elements with large amounts of missing data or frequent ‘Unknown’ answers should be considered for removal. To decrease the data cleaning burden and improve quality, free text fields should only be available when additional specifications are expected to be valuable. Expanding answers options and minimizing the availability of free text fields should also reduce intra- and inter-user variation and leaves less room for interpretation differences. Furthermore, system-automated data accuracy checks, such as calculations of surgery date after date of birth, should be implemented.

Secondly, completeness of follow-up data entry should be improved. One-year follow-up data entry might not have reached 100% completion rate as there may have been patients that have undergone their reconstructive surgery less than one year ago. Yet, more than 70% of the patients in this analysis whose records have missing data have undergone their reconstruction before 2020, suggesting that the time since reconstruction does not explain low completion rate. Another, more plausible explanation, is that users must independently remember to enter one-year follow-up data, without proper notification. To improve completeness for one-year follow-up, users should be automatically reminded by the EDC system if data is required a year after reconstruction. Although data for the remaining (closed-ended) elements in the registry was nearly complete, overall completeness should be improved by

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making the appropriate data elements mandatory to be filled in once starting the registration of a patient.

Thirdly, taking feedback from the users into account, it is recommended to conduct a critical evaluation of the clinical value of the current data elements. For example, current data on diagnostic tests, and whether additional diagnostic procedures (e.g., voiding cystourethrogram, cystoscopy, echocardiogram) should be considered. Additionally, the registry should improve the structure of data collection on whether the ARM is part of a syndrome. The list of syndromes should be elaborated and these, as well as the individual ARM types, should have corresponding standardized ontology codes, such as Orphanet Rare Disease Ontology (ORDO), Online Mendelian Inheritance in Man (OMIM), or the International Classification of Diseases (ICD) [24–26]. Furthermore, to improve the value of the follow-up data and based on user suggestions, the follow-up period should be extended to at least five years but ideally to lifelong, as ARM is a condition that continues to affect patients throughout their lives. Particularly because transitional, adult, and old-age outcome data are extremely scarce or incomplete for rare congenital diseases such as ARM. Long-term outcomes and longitudinal data collection should be facilitated through standardized case report forms at specific, predetermined time points, with automated reminders before and, if registration not completed, warning reminders after.

It is not only the ARM-Net registry that can benefit from this quality assessment, as there are many suggestions that are applicable to all rare disease patient registries. A recent systematic review [27] highlighted that many registries struggle with quality management and maintenance. Like the suggestions resulting from this study, protocolized periodical monitoring procedures, evaluations of user feedback, implementation of coding languages, and mandatory fields to promote completeness are amongst the recommendations to improve existing registries. Additionally, monetary incentives per registration, revision of research aims, and securing long-term sources of funding are important aspects to maintenance strategy [27].

Most importantly, registry developers and maintainers should recognize that no registry will be perfect from its establishment, and they should continuously be evaluated for improvement. Registries, even if they have been running for more than a decade such as the ARM-Net registry, are malleable and should consider changes and updates resulting from periodical quality assessments to remain relevant. Sustainability of registries is key and with this study, the authors call for other rare disease patient registries to take example to enhancing the small, but impactful field of rare disease research.

5. Conclusion

The ARM-Net registry collects information that is undeniably very valuable demonstrated by its consensus statements and publications. However, as the registry has outgrown its original purpose, data quality remains a challenge with vulnerability to error and tendency to intra- and inter-user variability. Nevertheless, users were satisfied with the ARM-Net registry. This quality assessment resulted in suggestions for improvement for the ARM-Net registry as well as other rare disease patient registries in general. Periodical critical (self-) evaluation is key to continuously improving data quality in the aspiration for a registry to be sustainable and remain relevant for future research and clinical care.

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Declaration of competing interest

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Appendix A. Supplementary data

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