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ARTHROPLASTY

The accuracy of reporting of periprosthetic joint infection to the Australian Orthopaedic Association National Joint Replacement Registry

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Aims

National joint registries under-report revisions for periprosthetic joint infection (PJI). We aimed to validate PJI reporting to the Australian Orthopaedic Association National Joint Arthroplasty Registry (AOANJRR) and the factors associated with its accuracy. We then applied these data to refine estimates of the total national burden of PJI.

Methods

A total of 561 Australian cases of confirmed PJI were captured by a large, prospective observational study, and matched to data available for the same patients through the AOANJRR.

Results

In all, 501 (89.3%) cases of PJI recruited to the prospective observational study were successfully matched with the AOANJRR database. Of these, 376 (75.0%) were captured by the registry, while 125 (25.0%) did not have a revision or reoperation for PJI recorded. In a multivariate logistic regression analysis, early (within 30 days of implantation) PJIs were less likely to be reported (adjusted odds ratio (OR) 0.56; 95% confidence interval (CI) 0.34 to 0.93; p = 0.020), while two-stage revision procedures were more likely to be reported as a PJI to the registry (OR 5.3 (95% CI 2.37 to 14.0); p ≤ 0.001) than debridement and implant retention or other surgical procedures. Based on this data, the true estimate of the incidence of PJI in Australia is up to 3,900 cases per year.

Conclusion

In Australia, infection was not recorded as the indication for revision or reoperation in one-quarter of those with confirmed PJI. This is better than in other registries, but suggests that registry-captured estimates of the total national burden of PJI are underestimated by at least one-third. Inconsistent PJI reporting is multifactorial but could be improved by developing a nested PJI registry embedded within the national arthroplasty registry.

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Introduction

The total number of people living with at least one arthroplasty in Australia is more than 800,000 and growing rapidly.[1] In 2019, 125,600 primary hip, knee, and shoulder arthroplasties were performed in Australia. One of the most devastating complications of arthroplasty is periprosthetic joint infection (PJI). In the same year, the incidence of PJI in Australia was estimated at between 2,200 to 2,900 cases per year.[2] A 2017 study looking at 3,705 Australian primary hip and knee arthroplasties revealed a two-year PJI rate of 1.7% (0.6% within four weeks, and 1.1% between four weeks and two years).[3]

National arthroplasty registries evaluate the outcome of joint arthroplasty surgery by linking primary procedures to subsequent revisions. Kaplan-Meier estimates of survival are used to report revision rates for all-cause revision and their indication. A revision is defined by the replacement, addition or removal of any component of the arthroplasty hardware. Recent publications assessing the

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validity of national joint registries in capturing infection as a complication have exposed gaps in reporting accuracy. Registries from Scandinavia and New Zealand under-report infection by up to 40%.[4-7] To assess the validity of PJI reporting, these studies compared PJIs captured by arthroplasty registries to data for the same cohort of patients collected by complementary registries or from hospital discharge diagnostic codes. Although these provide estimates of the proportion of under-reported PJIs, the denominator datasets may not provide patient-specific granular data to explore the patient and surgical factors associated with under-reporting. This might have particular relevance for under-reporting of reoperations for infection which would not be considered reportable. For the present study there were two distinct, but complementary aims. First, we aimed to test the validity of the Australian Orthopaedic Association's National Joint Arthroplasty Registry (AOANJRR) in identifying infection as an indication for revision and the clinical and surgical factors associated with PJI reporting accuracy. Second, we aimed to use this data to refine estimates of the true burden of PJI in Australia.

Methods

Patient population. A prospective cohort study of patients with confirmed PJI was matched to an independent arthroplasty registry. The primary cohort of patients was obtained through the Prosthetic Joint Infection in Australia and New Zealand Observational (PIANO) study, a large, prospective, observational study conducted at 27 hospitals across Australia and New Zealand (22 Australian centres and five New Zealand centres).[8] Between July 2014 to 31 December 2017, 783 patients with confirmed PJI were recruited across all centres at the time of diagnosis, with detailed data collected regarding clinical, laboratory and microbiological features, treatment strategies, and patient outcomes. Participants were followed for 24 months following PJI diagnosis. Of these, 561 patients recruited from the 22 Australian centres were identified from this cohort and their details were sent to the AOANJRR for data-matching.

The AOANJRR was established in 1999 with the purpose to improve and maintain the quality of care for individuals undergoing arthroplasty surgery in Australia. Between September 1999 and 31 December 2019, the registry captured 1,603,846 joint arthroplasties (694,730 hips, 849,329 knees, and 59,787 shoulders).[2] The reporting of arthroplasty procedures is voluntary Australia-wide for both public and private procedures. Data are verified against hospital separation data from each state and territory resulting in an almost 100% capture of national arthroplasty. Data regarding indications and dates for the primary arthroplasty procedure, as well as implant details, were supplied for all patients that had procedures recorded by the AOANJRR. This included details related to the primary arthroplasty and the indications and details relating to subsequent revision or reoperation procedures they were reported.

Procedures that are considered reportable to the AOANJRR include those in which major components are removed, with or without arthroplasty, or debridement, antibiotics, and implant retention (DAIR) procedures in which a new liner is implanted. Procedures in which the liner is removed, cleaned, and then re-implanted are not considered reportable to the AOANJRR, but are often still recorded by the registry. These reoperations are not included as revision procedures in AOANJRR statistics; however, they do provide data regarding infection as a complication of arthroplasty procedures.

Definitions. PJI was defined using the Infectious Diseases Society of America criteria.[9] Diagnostic criteria for entry into the PIANO study are provided elsewhere.[8] We defined early PJI as the date of diagnosis occurring ≤ 30 days following the original arthroplasty operation. Late acute PJI (LA-PJI) was defined as occurring > 30 days from implantation, but with a duration of symptoms ≤ seven days and no evidence of a sinus overlying the joint. Patients with a late onset infection (> 30 days from implantation) and a prolonged duration of symptoms (> 30 days) at the time of diagnosis, or the presence of a sinus, were considered to be late, chronic PJI. The remainder of PJI cases were considered unclassifiable or 'other'. Details regarding the definitions for primary treatment strategy at seven days from diagnosis and diagnostic criteria for PJI cases are provided elsewhere.[8] When the initial management strategy was not clearly identified, "no clear plan" was recorded as initial management strategy.

Statistical analysis. The accuracy of reporting for infection was assessed by determining the number of patients with confirmed PJI from the PIANO study that were captured by the AOANJRR divided by the total number of patients matched to the registry. The programme R was used for statistical analyses (R Foundation for Statistical Computing, Austria). Continuous data are presented as median and interquartile range (IQR) and comparisons between groups were by non-parametric tests. Comparisons between categorical variables were analyzed with a chi-squared test. Logistic regression multivariate analysis was performed. Variables with $p < 0.10$ on bivariate testing were included in the model using a backward stepwise approach and retained in the model if $p < 0.05$. The most parsimonious final model was chosen using Akaike information criterion and comparison of sequential models with analysis of variance. The results are presented as adjusted odds ratios (aORs) with 95% confidence intervals (CIs).

Ethics and consent. Linking the PIANO study data to the AOANJRR was one of the primary objectives of the PIANO study. All patients enrolled provided written informed consent to allow the data collected to be linked to the

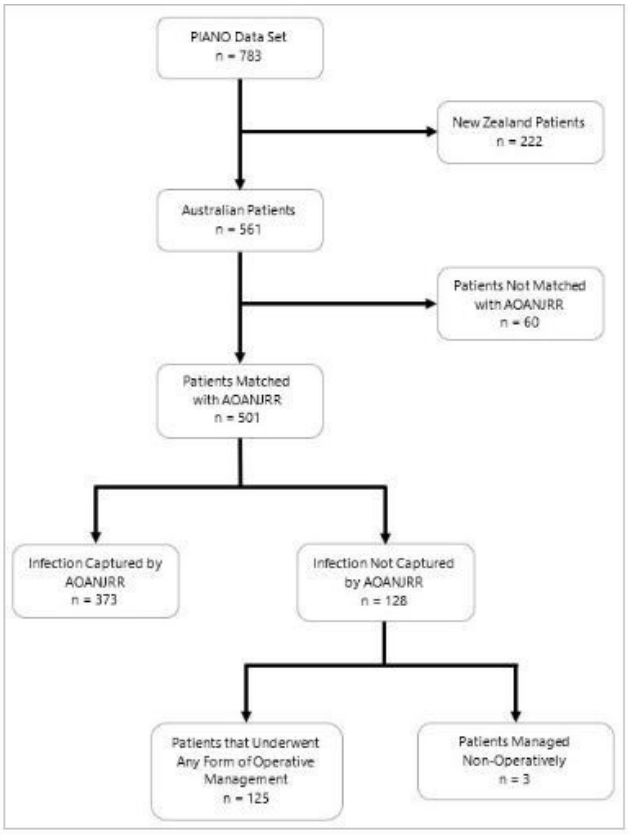

Fig. 1

Flowchart of study cases. AOANJRR, Australian Orthopaedic Association National Joint Arthroplasty Registry.

AOANJRR and details of their procedures to be extracted. Ethical approval was granted for the PIANO study and its linkage with the AOANJRR by all 22 Australian institutions involved and the study was registered (ANZCTR12615001357549).[8] No funding was provided for this sub-study.

Results

The PIANO study identified 561 Australian cases of confirmed PJI, 501 (89.3%) of which were matched with data available through the AOANJRR (Figure 1). From the data received from the registry, 373 recorded a revision procedure for infection while 128 did not. Only three of the 128 cases with an infection diagnosis were managed nonoperatively (and therefore not reportable to the registry), meaning that a total of 125 cases (25.0%) were not reported to the registry as an infection, despite receiving operative management for a confirmed PJI. The clinical and microbiological characteristics, indication for index arthroplasty, and initial surgical management strategy for participants with confirmed PJI according to reporting status to the registry are shown (Table I).

The overall median age of all cases matched to the AOANJRR was 69 years (IQR 61 to 77; range 31 to 99), with 269 males and 232 females. There were 200 hip, 277 knee, 21 shoulder, one ankle, and two elbow arthroplasties. Debridement, antibiotics, and implant retention (DAIR) was the initial management strategy for the majority of cases (318; 63.5%). This was followed by two-stage revision (96; 19.1%), suppressive antibiotics (41; 8.2%), single-stage revision (23; 4.6%), "no clear plan" (19; 3.8%), then excision arthroplasty (four; 0.8%).

Bivariable comparisons between reported and not-reported cases demonstrated highly significant differences in PJI type and the initial management strategy (Table I), which were included in the most parsimonious logistic regression model. When compared with late acute PJI, early (within 30 days of implantation) PJIs were less likely to be reported (aOR 0.56 (95% CI 0.34 to 0.93); p = 0.020). There were no significant differences for chronic or other PJI types. Compared with DAIR procedures, two-stage revision procedures were more likely to be reported correctly as a PJI to the registry (aOR 5.3 (95% CI 2.37 to 14.0); p = <0.001). There were no significant differences for other procedures. Age, sex, location of index joint, and microbiological characteristics were not associated with reporting to the registry. There were no significant regional differences in reporting.

Characteristics of patients with PJI that were not reported to the registry. Of the 125 cases that were not reported to the AOANJRR as infection, 96 (76.8%) did not have any revision or reoperation procedure recorded by the registry, despite operative management for the PJI. Using the PIANO data as the reference, most (77; 80.2%) of these had a DAIR procedure as the primary surgical strategy. Here, 27 (35.1%) did not have a liner exchange, while 43 (55.8%) had components exchanged but were not reported. Whether a component was exchanged or not was not recorded in the PIANO dataset in seven of these cases. Component exchange was not associated with under-reporting (p = 0.310).

The remaining 29 cases (23.2%) not reported to the AOANJRR as infection did have a revision recorded, but not with infection as the indication. Reported indications for revision or reoperation are shown according to PJI type and surgical management strategy (Table II). Among these patients, 18 had loosening, lysis, or metal-related pathology reported as the indication which varied according to PJI type and surgical management strategy. The remaining 11 patients had fracture, implant breakage, dislocation, malalignment, instability, or patella erosion as indications for revision (Table II).

Patients not matched to the AOANJRR. Of the 561 Australian cases of PJI captured by PIANO, 60 were not matched to the AOANJRR. Overall, 14 of these cases preceded the establishment of the registry; however, 46 cases had their primary arthroplasty procedure after data recording commenced, but still evaded capture all together.

Table I. Clinical and microbiological characteristics, and initial surgical periprosthetic joint infection (PJI) management strategy according to reporting to the Australian Orthopaedic Association National Joint Arthroplasty Registry.

Variable	Total, n = 501*	Reported as reoperation for infection, n = 376*	Not reported as reoperation for infection, n = 125	p-value†
Median age, yrs (IQR)	69 (61 to 77)	69 (62 to 76)	69 (61 to 78)	0.560
Male sex, n (%)	269 (53.7)	204 (54.7)	65 (52.0)	0.660
State, n (%)				
New South Wales	152 (30.3)	104 (27.6)	48 (38.4)	
Queensland	36 (7.2)	30 (8.0)	6 (4.8)	
South Australia	45 (9.0)	36 (9.5)	9 (7.2)	
Tasmania	24 (4.8)	15 (4.0)	9 (7.2)	
Victoria	69 (13.8)	56 (14.9)	13 (10.4)	0.090
Western Australia	175 (34.9)	135 (36.0)	40 (32.0)	
Joint, n (%)				
Knee	277 (55.3)	211 (56.1)	66 (52.8)	
Hip	200 (39.9)	150 (39.9)	50 (40.0)	
Shoulder	21 (4.2)	14 (3.7)	7 (5.6)	
Elbow	2 (0.4)	0 (0.0)	2 (1.6)	0.330
Ankle	1 (0.2)	1 (0.3)	0 (0.0)	
Indication for infected arthroplasty, n (%)				
Primary	406 (81.1)	302 (80.3)	104 (83.2)	
Revision	90 (17.9)	72 (19.2)	18 (14.4)	0.250
Unknown	5 (1.0)	2 (0.5)	3 (2.4))	
PJI type, n (%)				
Early	121 (24.2)	77 (20.5)	44 (35.2)	
Late acute	207 (41.3)	158 (42.0)	49 (39.2)	
Chronic	110 (21.9)	96 (25.5)	14 (11.2)	< 0.001
Other	63 (12.6)	45 (12.0)	18 (14.4)	
Initial PJI management plan, n (%)				
DAIR	318 (63.5)	223 (59.3)	95 (76.0)	
Two-stage revision	96 (19.1)	90 (23.9)	6 (4.8)	
Single-stage revision	23 (4.6)	17 (4.6)	6 (4.8)	
Excision arthroplasty	4 (0.8)	2 (0.5)	2 (1.6)	
Suppressive antibiotics	41 (8.2)	33 (8.8)	8 (6.4)	< 0.001
No clear plan	19 (3.8)	11 (2.9)	8 (6.4)	
Microbiology, n (%)				

Continued

Table I. Continued

Variable	Total, n = 501*	Reported as reoperation for infection, n = 376*	Not reported as reoperation for infection, n = 125	p-value†
Monomicrobial	342 (68.2)	260 (69.1)	82 (65.6)	
Polymicrobial	103 (20.6)	79 (21.0)	24 (19.2)	
Culture negative	56 (11.2)	37 (9.9)	19 (15.2)	0.250
Microbiology species, n (%)				
Staphylococcus aureus	201 (40.1)	154 (41.0)	47 (37.6)	
Enterobacterales	38 (7.6)	24 (6.4)	14 (11.2)	
Beta-haemolytic streptococci	51 (10.2)	39 (10.4)	12 (9.6)	
ESCAPPM organism	42 (8.4)	30 (7.8)	12 (9.6)	0.060
Coagulase-negative staphylococci	37 (5.6)	34 (9.0)	3 (2.4)	

*Includes three patients who did not receive any operative management.
†Comparisons between categorical variables were analyzed using a chi-squared test. Sequential models were compared using analysis of variance.
DAIR, debridement, antibiotics, and implant retention; ESCAPPM, Enterobacter, Serratia, Acinetobacter, *Proteus vulgaris*, Providencia, and Morganella species; IQR, interquartile range.

Table II. Recorded indications for revision in 29 participants with confirmed perirprosthetic joint infection (PJI) where infection was not reported as a reason for revision to the Australian Orthopaedic Association National Joint Arthroplasty Registry, according to PJI type and surgical management strategy.

PJI type	DAIR (n)	Two-stage revision (n)	One-stage revision (n)	Suppressive antibiotics (n)	No clear plan (n)	Excision arthroplasty (n)
Early (n = 10)	Fracture (1) Implant breakage (1) Loosening (4) Patella erosion (1) Dislocation (2)				Fracture (1)	
Late-acute (n = 10)	Dislocation (1) Loosening (1) Lysis (2) Metal-related pathology (2)	Dislocation (1)	Rotator-cuff insufficiency (1)	Loosening (1) Malalignment (1)		
Chronic (n = 4)		Loosening (1)	Loosening (2)	Loosening (1)		
Other (n = 5)	Loosening (1) Lysis (1) Fracture (1)		Lysis (1)			Loosening (1)

DAIR, debridement, antibiotics, and implant retention.

Discussion

It has been shown previously that arthroplasty registries under-report infection by up to 40%.[4–7,10] With near universal coverage for arthroplasty operations in Australia, the AOANJRR successfully identified 75%, but did not capture 125 cases of PJI (25%). Only three of the 501 cases matched between the two databases were managed nonoperatively, meaning that a significant proportion of the PIANO population evaded detection by the AOANJRR, despite undergoing some form of operative management for their confirmed PJI. Comparable data from Scandinavia and New Zealand suggests that the Australian registry is performing better than other registries in this regard, with reporting accuracy of 63%, 67%, and 67% PJI for New Zealand, Denmark, and Sweden, respectively.[4-7]

To date, there are few data exploring factors associated with reporting accuracy of revision for infection to registries. In the present study, patient demographics, location of joint, microbiological features, or any regional differences between states did not influence the reporting of PJIs to the AOANJRR. The temporal type of PJI influenced rates of reporting, with early (within 30 days of implantation) PJIs being less likely to be reported when compared with late acute PJI (OR 0.56 (95% CI 0.34 to 0.93); p = 0.020).

Two-stage revision procedures were more likely to be reported correctly as a PJI to the registry when compared

with other surgical management (OR 5.3 (95% CI 2.37 to 14.0); p ≤ 0.001). These results accord with a smaller cohort from New Zealand, which identified debridement and modular exchange procedures, rather than two-stage revision procedures, as a possible risk for under-reporting.[7]

Although the logistic regression model identified broad independent predictors for non-reporting, our data suggest that outside these factors the specific reasons for non-reporting are multifactorial and inconsistent. It is also important to note that there may be valid reasons for not capturing every PJI in the registry. The basic concept for reporting to the AOANJRR is that events are recorded in relation to revision procedures. For most surgeons this would imply the exchange or removal of at least one of the arthroplasty components. Therefore, operations without component exchange may not be recorded as a revision for PJI and may therefore be responsible for some of the missed PJIs. Indeed, of the 96 revisions for PJI that were not recorded in the joint registry, 77 had a DAIR procedure, and of these, 27 had no component removed. It is plausible that this observation could be explained by surgeons not wanting to be recorded as having a PJI on the registry or being unaware that a liner exchange is considered reportable to the registry.

Timing of the operation may also be important for accurate reporting. Notification of the indication for revision is completed for the AOANJRR at the time of surgery. A delayed or unexpected diagnosis of infection may elude capture by the registry especially if microbiological confirmation is reported days or weeks after the procedure. In our study, this was evidenced by the variety of reported indications reported to the registry according to heterogeneous PJI types and surgical management strategies. The 29 patients with an alternative indication for revision (loosening, lysis, or metal-related problems) might reflect delayed and perhaps unexpected microbiological confirmation of PJI, rather than deliberate misreporting by surgeons. One proposed solution to this is to postpone reporting, which may allow further details and definitive culture reports to become available. The trade-off for this delay is that it might impact on completeness of reporting.[10]

The key strength of this study lies in the reference cohort with confirmed PJI, which was based on a large prospective observational study collected across 22 sites within Australia. By recruiting from multiple institutions these data are generalizable in terms of PJI characteristics and management approaches across the country.[8] A significant amount of detailed data was collected for all patients involved in this study allowing exploration of the clinical, laboratory, and microbiological characteristics associated with PJI reporting.

Our study has limitations. We did not examine the individual reporting forms or intraoperative findings of each case and so cannot confirm the accuracy of the reported information. The AOANJRR reporting forms are often filled out by non-surgical personnel or nursing staff at some point during the procedure and so may either not reflect the correct initial diagnosis or may not account for intraoperative developments, such as infective findings during revision procedures. Another limitation is that PJIs managed without operative intervention with suppressive antibiotics, which are not reportable to the AOANJRR and therefore may not be reflected in the reported incidence of PJI. The PIANO study identified 41 cases of PJI that were managed with suppressive antibiotics; all but three of these cases progressed to a revision procedure at some stage. As noted in the consort diagram, these latter patients were 'correctly' not reported to the registry. The final limitation is the representativeness of the institutions contributing to the PIANO data, which might have affected the reporting rates. While we recruited from 22 secondary and tertiary institutions across different Australian states, comprising public and private institutions, it is possible that this might not be reflective of PJI reporting for all institutions across Australia.

The AOANJRR correctly identified 75% of patients in the PIANO study. There are global calls to nest PJI registries within arthroplasty registries to monitor secular trends in PJI, and as a platform for large scale intervention trials.[11] To improve the overall capture rate of all PJI, our data suggest that 'mandatory' reporting of all DAIR procedures, regardless of whether the liner was exchanged would reduce under-reporting by ~60%. The other major modification to improve PJI reporting accuracy would be to automate linkage of microbiological data collected at the time of surgery.[8,10] This would capture microbiologically confirmed cases that may not have been expected at the time of operative management. Linked microbiological data would also be integral to enable large scale nested randomized controlled trials within the AOANJRR. One further measure would be to enable more than one diagnosis to be reported on the reporting form. This could include 'suspected infection', alongside other possible indications for revision.

Of the patients not matched to the AOANJRR, 14 of the 60 unmatched cases preceded the establishment of the registry. Overall, 46 cases had their primary arthroplasty procedure after data recording commenced, but still evaded capture by the AOANJRR. This is concerning as this number is higher than expected given Australia's near complete reporting compliance, and it is unclear to us why this has occurred. An error in data matching between our study databases or an error in the initial collection of patient demographics by the registry are our most likely hypotheses.

Revised estimates of prosthetic joint infection. Based on the latest figures from the AOANJRR 2020 annual report, the incidence of PJI in Australia is estimated to be

between 2,200 to 2,900 cases per year.[2] Given that our study shows that the registry failed to capture 25.0% of known PJIs, it is reasonable to assume that this value is under-estimated by approximately one-third. This is likely to be a conservative estimate as a further 60 of the 561 Australian patients (10.2%) with confirmed PJI could not be matched to the registry. Based on our results, a more accurate estimate of the incidence of PJI in Australia to be up to 3,900 cases per year and implies a much larger impact of PJI to the Australian health sector than previously thought. The mean cost for each case of PJI in Australia in 2013 was estimated to be $69,414 (standard deviation $29,869).[12] Our revised estimate of the incidence of PJI in Australia represents costs to the Australian healthcare system in excess of $50 million per year.

In conclusion, in Australia, infection was not recorded as the indication for reoperation in one-quarter of those with confirmed PJI. This is a lower proportion than in other comparable registries and studies, but suggests that registry-captured estimates of the total national burden of PJI are under-estimated by one third. Broadly, early PJIs were less likely to be reported to the AOANJRR, while two-stage revisions were more likely to be reported compared to DAIR procedures. With the data we have collected, a revised estimate of the incidence of PJI in Australia could be up to 3,900 cases per year, representing a significantly higher economic and social burden on the Australian community than had previously been thought. More robust reporting of all DAIR procedures and a mechanism to link to microbiological data could improve PJI reporting rates and facilitate nested PJI trials within the arthroplasty registry.

Take home message

- The Australian Orthopaedic Association National Joint Replacement Registry underestimates revision for infection by one third.
- Based on our analysis, a revised estimate of the incidence of periprosthetic joint infection (PJI) in Australia is up to 3,900 cases per year.
- Inconsistent PJI reporting is multifactorial but could be improved by developing a nested PJI registry embedded within the national arthroplasty registry.

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- M. Lorimer: Formal analysis, Software, Writing – review & editing.
- R. de. Steiger: Project administration, Resources, Validation, Writing – review & editing.
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