Is Icare as Accurate as Goldmann or Perkins Applanation Tonometry at Measuring Intraocular Pressure in the Setting of Suspected or Diagnosed Congenital Glaucoma?: A Systematic Review

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ABSTRACT

Background: The present study aims to analyse the accuracy of iCare rebound tonometers, compared to the gold standard Goldmann or Perkins applanation tonometry in congenital glaucoma patients and suspects.

Methods: Two individual researchers were tasked with individually searching five different databases, including Medline, Embase, CINHAL, Cochrane and Elsevier/Scopus, using preidentified keywords and terms. Following this, each researcher then screened the results to rule out any that did not meet strict selection criteria or were outside the scope of the present study. Selection criteria pertained to age of participants, tonometry tools used and whether participants were either congenital glaucoma suspects or patients already diagnosed with congenital glaucoma and being monitored. The two researchers than reconvened to discuss individual results and mitigate any discrepancies in results. All studies were then assessed via the Critical Appraisal Skills Programme Checklist (CASP) and QUADAS-2 tools for risk of bias. Following this, five studies were included in the reports analysis.

Results: Within the five included studies, there were a total of 580 eyes, all of which were affected by a form of congenital glaucoma. There were no limitations on the type of glaucoma included, whether that be primary, secondary or normal tension glaucoma, and all participants were below 18 years of age. Overall results showed a positive consistency and accuracy between the two devices, but arguments were made against the tools interchangeability. Additionally, the results presented in some studies were recommended within select parameters for which these results can be applicable.

Conclusion: In a vast majority of cases, iCare or rebound tonometry can be interchanged with Goldmann applanation tonometry to ease the measurement of intraocular pressure in a paediatric setting. This suggests that in most clinical cases clinicians should be able to utilise iCare for ease of measurement without risk of over or underestimating intraocular pressure.

Keywords: iCare, applanation, glaucoma, congenital, child

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Accepted for publication: 5th December 2022

INTRODUCTION

Congenital glaucoma is an uncommon subcategory of early onset glaucoma, characterised by onset before age 18 years.[1] This condition causes pressure increase in the eye, often due to inadequate aqueous outflow, particularly affecting the optic nerve.[2] Without proper management, it has the potential to cause vision loss during childhood.[3] In Great Britain, childhood glaucoma causes blindness in 1.2% of children, 3% in northern India and 7% in southern India.[4] In the United States, prevalence has been recorded up to 2.29 for every 100,000 patients under 20 years of age.[5]

Clinically, diagnosis and management are often difficult due to the uncooperative nature of children and requires ophthalmologists with focused training.[6] The current gold standard for intraocular pressure (IOP) measurement is Goldmann applanation tonometry or the handheld Perkin's version. This measurement is useful as it is the main modifiable risk factor in glaucoma.[7] However, due to proximity and reliance

on patient stability, it often requires testing under general anaesthesia or is otherwise unable to be tested at all.

The recent introduction of rebound tonometers, namely iCare, has provided hope in advancing the ease of childhood IOP measurement. These tonometers have minimal surface contact and provide rapid readings,[7] thus suggesting viability in younger populations. In some cases, rebound tonometers can eliminate the need for general anaesthesia or reduce the amount of time spent obtaining measurements in sedated children.[7] However, reliability must be assessed to ensure it compares to Goldmann or Perkins. If reliability is lacking and results too disparate, this may perhaps render them unusable in congenital glaucoma.

Despite this, literature regarding the reliability of such devices compared to the gold standard has been limited. Recently, only one systematic review has been undertaken, including a variety of studies. It included both healthy and congenital glaucoma participants and suggested that literature was limited and could only infer that rebound tonometry may be reasonably accurate and suggested more research was required to 'assess … the differences between instruments'.[8] As such, this systematic review aims to update these suggestions, as literature has developed. However, the present study, unlike the prior, will focus solely on the reliability of iCare in children with congenital glaucoma or suspects.

The present study will primarily focus on whether iCare rebound tonometers (RBT), the index test, provide reliable intraocular pressure measurements that are comparable to Goldmann applanation tonometer (GAT) or Perkins's tonometers (PAT), the reference standards. This study will only include children with congenital glaucoma or suspects to establish the potential for RBT to enhance the efficiency of care, and ease of diagnosis and monitoring in congenital glaucoma.

METHODS

Eligibility criteria

The population included in the systematic review were children aged under 18 years of age, with a diagnosis or suspected diagnosis of congenital glaucoma, who had their intraocular pressure measured clinically using GAT, PAT or iCare. Also, only completed studies, published from 2003 to 2021 were sought, with the year 2003 being nominated as it is the year that iCare was introduced clinically. Studies without an English version available were excluded and whilst no restrictions were placed on study design, due to the nature of results required, letters to the editor, conference abstracts and alike publications were excluded.

The primary outcome was the achievement of reliable and accurate IOP measurements to assist in the diagnosis and monitoring of congenital glaucoma. Additional secondary outcomes also included early diagnosis of congenital glaucoma, improvement in the disparity of IOP measurements on repeat testing, economic consequences and patient satisfaction.

Identification of studies

Both authors conducted separate searches of several online databases to obtain studies for the review. These included Cochrane Central Register of Controlled Trials, PubMED (Medline), CINHAL, Embase and Scopus. The following search strategy was applied to all databases: *('iCare' OR 'Rebound') AND ('Goldmann' OR 'Applan*' OR Perkins) AND ('Glaucoma' AND 'Congenital' OR 'Infant*' OR 'Paed*' OR 'Juvenile') AND ('Intraocular Pressure' OR 'IOP').*

Additional limits such as English language and human subjects were placed on the searches. Also, the publishing dates were restricted to 2003 - 2021. All database searching was conducted between the 14th and 16th of September 2021. No grey literature was searched for the purposes of this review. Furthermore, only studies that were approved by an appropriate ethics committee and obtained informed participant consent were selected.

Study selection

Initially, both reviewers completed all database searches. Then duplicates were identified and removed. The remaining titles and abstracts were screened for relevance, utilising the eligibility spreadsheet (Table 1) to identify inclusion suitability. Any discrepancies between the two reviewers were resolved by discussion.

All studies that appeared to meet selection criteria were then obtained in full hard copy by both authors via the La Trobe Library database. All full articles located were then progressed into the data extraction phase.

The utilisation of regimented selection criteria ensured all studies were considered through an ethical lens. Additionally, neither author received any financial support or maintained any relationships that may, or may be perceived to, pose a conflict of interest.

Data extraction and critical appraisal

Customised excel spreadsheets, generated by the authors were then utilised in data extraction. Table 2 shows that data was extracted regarding patient age, gender/ethnicity, diagnosis stage, IOP recording/s, risk of bias, study design, methodological reliability, and whether the two tools were comparable. It should also be noted that two independent reviewers participated in each step of data extraction.

In addition to these stated categories, the independent researchers both recorded important and potentially useful

Table 1. Eligibility spreadsheet				
Researcher name:				
Screening section				
Title, author & journal	**Database (Medline, Embase, Scopus)**	**Inclusion and exclusion data** 1. Includes iCare AND Goldmann/Perkins applanation 2. Congenital glaucoma patient or suspect 3. Participants 0-18 yrs only 4. Published between 2003-current 5. Completed study (not including protocol, trials, etc) 6. Conducted in health care setting 7. English language 8. Human subjects	**General information from abstract** (including reason for exclusion)	**Decision** (if NO, turn line red)
		Met/Not Met		Y/N

information regarding the participants. For example, in the patient diagnosis stage section, which was titled 'Congenital glaucoma patient or suspect' in Table 2, the researchers also recorded a breakdown of types of glaucoma diagnosed, whether it be primary or secondary congenital glaucoma. Researchers were also able to report on prior glaucoma treatment, including pharmacological drops usage or prior surgery.

Data pertaining to risk of bias was assessed through the QUADAS-2 tool.[9] Only studies that were deemed to have an overall low risk of bias were deemed relevant. Moreover, the methodological reliability of individual studies was determined by applying the Critical Appraisal Skills Programme (CASP) Diagnostic Checklist to each study.[10]

The study selection and extraction process was documented using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Figure 1) for each selector.

Data synthesis and analysis

The data collected from the included studies was summarised and the quality of each study discussed. The nature of the data collected meant that some components were synthesised via tabulation or graphs, whereas others were presented narratively.

Descriptive details such as study design, patient characteristics, validity, reliability and diagnostic tools used were synthesised narratively. Qualitative data pertaining to the IOP measurements was analysed by generating approximate graphs, with data estimated from figures and plots in the included studies (Figure 2).

Table 2: Extraction spreadsheet												
Researcher name:												
Data extraction:												
Article title	Notes	Age range	Gender	Ethnicity	Congenital glaucoma patient or suspect	Measurements taken	IOP recorded (for both tools)	iCare comparable?	Notes on secondary outcomes	Risk of bias assessment	Study design	Methodology reliability

Figure 1. PRISMA flow diagram.

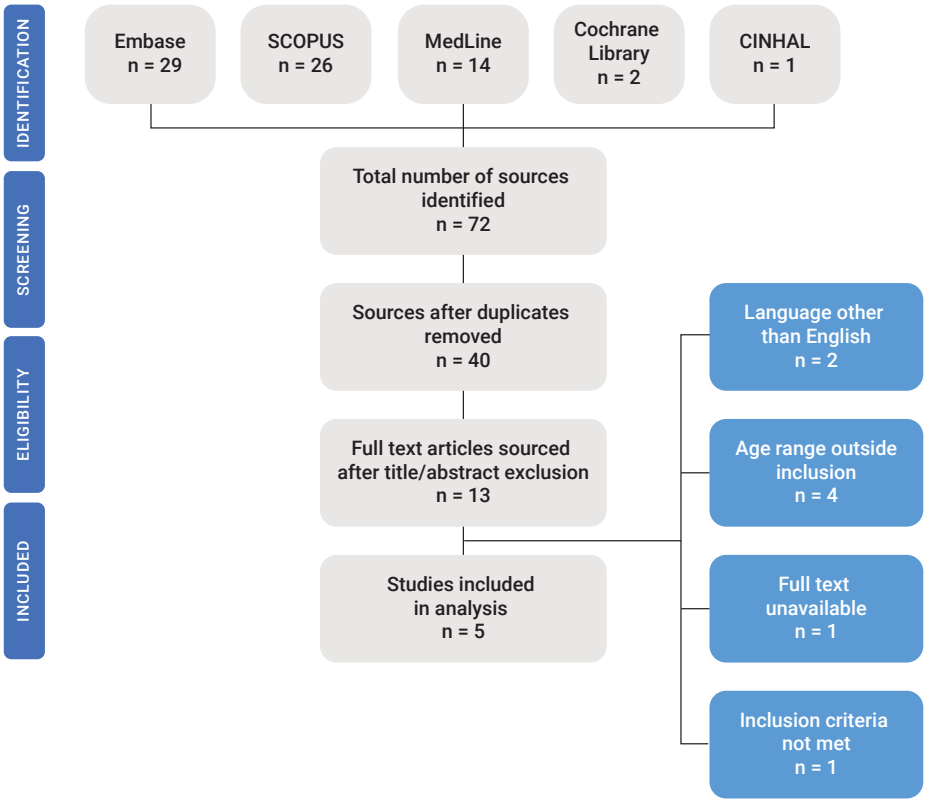
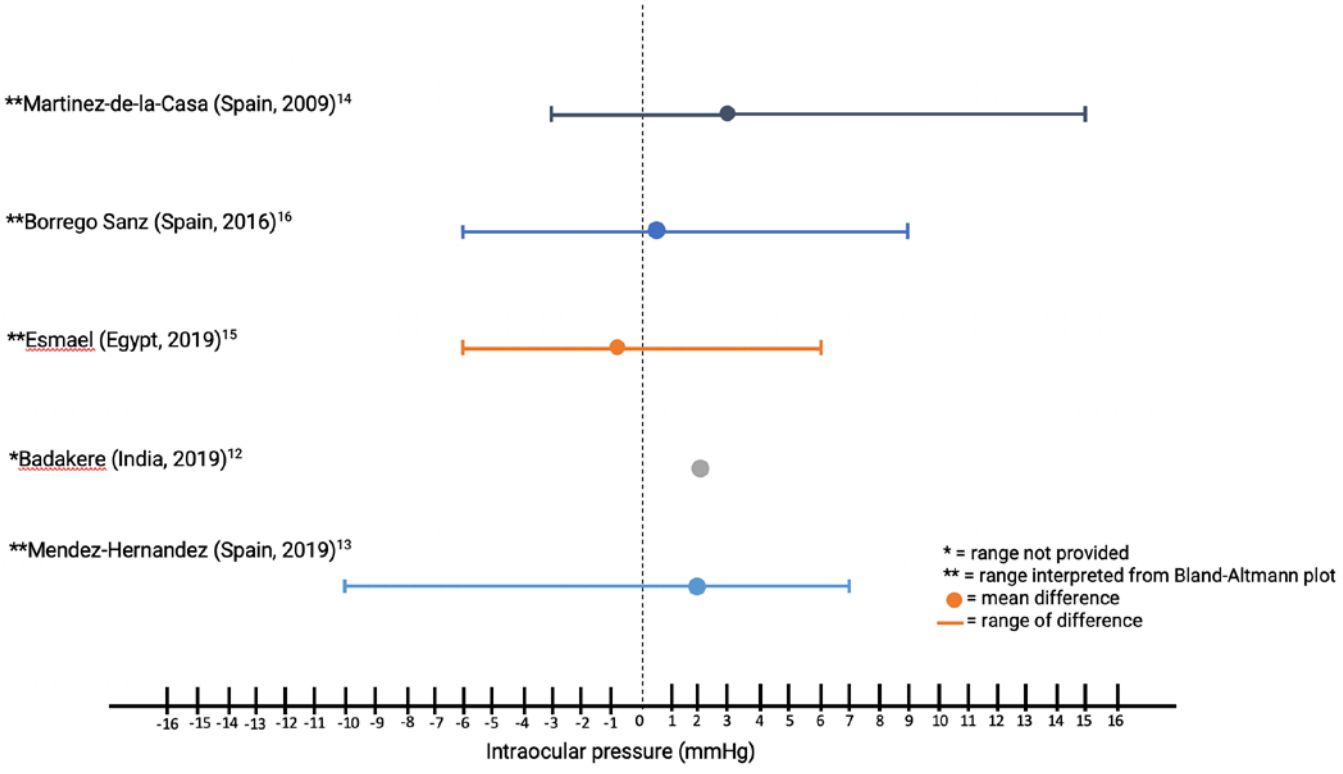


Figure 2. Graphical estimation of results for included studies: Comparison of mean difference and range of difference.



RESULTS

Search results

Database searching presented a plethora of literature, totalling 72. The PRISMA flow diagram outlines the search process in Figure 1. Embase presented the greatest number of results (29), followed by Scopus (26), MedLine (14), Cochrane (2) and CINHAL (1). Following duplicate removal, 40 remained. Search results were assessed via analysis of title and abstract, looking for prespecified inclusion/exclusion data. Researchers compared chosen articles, resulting in a final 13 being included. Full text articles were then sought and a further eight articles were excluded. Exclusions were due to full text being in another language (2), ages outside inclusion range (4), and having no full text available (1). The previous systematic review was the eighth excluded as it included healthy patients and results analysis focused on both healthy children and those with congenital glaucoma, thus researchers felt it failed to meet the present study's population. Regarding the full text that was unable to be sourced, the researchers were unable to obtain the full presentation for the conference abstract and as such, given the limited nature of information provided in the abstract alone, this text was forced to be removed from the present study.[11]

Study characteristics

In the included articles, all children were under the age of 18 years and of either gender. Patients all had variable glaucoma-related history. Some participants had prior surgery noted, and some others had previous pharmacological treatment, including drops. Additionally, it was noted that some patients had undergone or were continuing to undergo both forms of treatment. All participants involved had either primary (PCG) or secondary congenital glaucoma (SCG), whilst it seems no suspects were included in any study.

Badakere et al included 106 eyes in the clear cornea group, rendering it the most eyes assessed in any of the studies.[12] For the purposes of this review, the remaining scarred cornea eyes were excluded. In comparison, the other studies featured smaller cohorts, with 91 eyes included by Mendez-Hernandez et al,[13] 68 by Martinez-de-la-Casa et al and 62 by Esmael et al.[14,15] The smallest sample size was the Borrego Sanz et al study which featured only 50 eyes, less than half the size of the largest study.[16]

All participants were below age 10 in the Badakere et al study,[12] similar to the average upper age range found in various other studies. Of the included studies, Mendez-Hernandez et el had the youngest upper age range of 31 months,[13] whilst Esmael et al had the oldest upper age limit of 16 years.[15] Past ocular history varied amongst the studies with some making no mention of ocular history, such as Esmael et al and Badakere et al,[12,15] whilst others did include this information.[13,16] Borrego Sanz et al reported that 30% of the congenital glaucoma patients included in the study were using at least one medicated drop and 65% had undergone at least one previous ocular surgery, although it was not explicitly stated as to whether all these surgeries were glaucoma related.[16] Similarly, Mendez-Hernandez et al reported a similar rate of medicated drop users, with 39.6% of participants on a medicated glaucoma drop.[13]

Gender of participants was another variable that was only reported in some studies. Whilst Mendez-Hernandez et al presented a specific percentage of each gender,[13] Martinez-de-la-Casa et al and Borrego Sanz et al only provided ratios of male to female.[14,16] Interestingly, Badakere et al presented a gender ratio of 32:30 but did not provide any direct indication of which was male or female, however convention may suggest males are presented first.[12] Esmael et al was the only study which did not present any gender information.[15] Of the three studies which provided specific gender information, males outweighed their female counterparts in two of the studies,[13,16] whilst only Martinez-de-la-Casa et al had more females than males.[14]

Regarding the geographical location of the studies, three were performed in Spain.[13,14,16] Outside of these European studies, Badakere et al performed their research in India, and Esmael et al in Egypt.[12,15] Of the included studies, Martinez-de-la-Casa et al is the oldest study, having been conducted in 2009.[14] Mendez-Hernandez, Badakere and Esmael et al all performed their studies 10 years later in 2019,[12,13,15] with Borrego-Sanz et al performing their research in between these years, during 2016.[16] Four of the included studies were cross-sectional studies,[12,13,14,16] whilst only Esmael et al did not note whether it was cross-sectional, instead deeming their own study a prospective, non-interventional study.[15]

Consecutive recruitment was noted in two of the studies,[12,13] whilst the others either did not recruit consecutively[15] or made no mention of the recruitment process.[14,16] Uniquely in the Martinez-de-la-Casa et al study,[14] the order of tonometer was randomised, and this system was not mentioned as having been employed in any of the remaining studies. Also in this same study, there was a loss of participants due to an inability to garner readings in some patients from either tool.[14] Borrego Sanz, Mendez-Hernandez and Badakere et al all obtained most results during an examination under anaesthetic (EUA),[16,13,12] whilst the remaining two studies obtained results without the need for general anaesthesia.[14,15]

A summary of study characteristics can be found in Table 3.

Study quality

Quality of included studies was analysed for reliability and bias using the CASP Diagnostic Study Checklist.[10] All studies addressed a clear question and provided necessary explanations. Several studies reported ambiguous details or did not report some measures which made study quality

Table 3. Study characteristics

	Number of participants	Number of eyes	Age	Gender	Glaucoma status/type
Mendez-Hernandez et al (Spain, 2019)[13]	n = 46	n = 91	Mean = 29.1 months Range = 13 - 31 months	47.3% F 52.7% M	69.2% PCG 30.8% SCG
Badakere et al (India, 2019)[12]	n = 89	n_{total} = 148 n_{CC} =106 $n_{CC(PCG)}$ = 79 $n_{CC(SCG)}$ = 27	Median = 2 years Range = 0.5 - 8 years	32:30**	PCG* SCG* (SWS, ASD, AND)
Esmael et al (Egypt, 2019)[15]	ntotal = 115	n_{total} = 223 n_{PCG} = 62	Mean = 7 years Range = 8 - 192 months (~16 years)	*	27.8% PCG 72.2% healthy control
Borrego Sanz et al (Spain, 2016)[16]	n = 50	n = 50	Mean = 33.54 months Range = 5 - 88 months	26:24 M:F	100% PCG (HS included)
Martinez-de-la-Casa et al (Spain, 2009)[14]	n = 68	n_{total} = 68 n_{LTR} = 5 n_{LTA} = 16 n_{final} = 47	Mean^ = 8.8 years Range^ = 3 - 13 years	19:28 M:F	100% CG (HS included)

CG = congenital glaucoma primary or secondary not specified, PCG = primary congenital glaucoma, SCG = secondary congenital glaucoma, SWS = Sturge-Weber syndrome, ASD = anterior segment dysgenesis, AND = aniridia, CC = clear cornea, HS = Haab's striae, LTR = lost to rebound, LTA = lost to applanation, * = statistics/number not recorded, ** = gender ratio not specified as M:F or F:M, ^ = of final eyes included in analysis (n=47)

assessment difficult, however this was overcome via discussion of understanding and interpretation between the systematic review researchers. It was important to note that one of the studies was not deemed as having detailed the methodology in sufficient detail and whilst this study remained a part of the current review, its results and implications was considered relative to the lack of clear methodology.[14]

QUADAS-2 highlighted two studies had low risk of bias and applicability concerns.[9,13,16] Esmael et al displayed high and unclear risks in various categories.[15] These categories included risks in patient selection, as recruitment was not consecutive or random and had highly selective selection criteria.[15] Further to this, when recording results examiners were not masked to the results of the gold standard.[15] Badakere et al had unclear and high-risk concerns in domains one and four as it was unclear whether attempts were made to avoid inappropriate exclusions and the effects of EUA were not deeply analysed as flow and timing of the study were not explicitly explained.[12] This thus raised concerns regarding patient applicability to the present study. Finally, Martinez-de-la-Casa et al had unclear and high risks in domain two as order of tonometer was randomised causing concern about the effects of applanation prior to rebound.[14] Domain three was therefore also of concern as the

process of conducting the reference standard was not highly specified. Domain four highlighted a high risk of bias in flow and timing and was accentuated by the loss of multiple participants, thus affecting applicability.[14]

Results of individual studies

The majority of the studies included in the present study were able to demonstrate good correlation between RBT and PAT in congenital glaucoma patients. Almost all studies, with the exception of the Martinez-de-la-Casa et al study,[14] showed positive, statistically significant results, most with a p value below 0.05, signifying that the difference between the two tools in each patient would fall between the 95% limits of agreement. The mean differences and range of differences, along with a simplified breakdown of overall results, can be found in Table 4.

Of the four studies that found the two tools to be comparable, Borrego Sanz et al found the smallest discrepancy between the two tools, presenting a mean difference of only 0.42mmHg. However, it is important to note that there was a p value of 0.42 which limits the reliability of such close results.[16] Despite this, Borrego Sanz et al were not alone in their discovery of the proximity between tonometry methods, as Esmael et al came close to the same result reporting a -0.79mmHg mean difference.[15] As both studies were able to show such close similarity between methods, this suggests a very positive consistency.

Badakere et al and Mendez-Hernandez et al also reported very similar results. For Mendez-Hernandez et al, the mean difference was found to be 2.18mmHg between iCare and Perkins,[13] with Badakere et al reporting a 2mmHg mean difference.[12] Through this, it is possible to see that both studies aligned in agreeing that the two methods of measurement were relatively similar and thus interchangeable.

The range of difference found in each study was largely variable. In some studies, the range of difference was clearly stated whilst others left range to be interpreted loosely from Bland-Altman plots. Of those that did rely on Bland-Altman plots, Mendez-Hernandez et al estimated a -10 to 7mmHg difference,[13] which was not too disparate from the Bland-Altman interpretation of -6 to 6mmHg found by Esmael et al.[15] In the case of the Badakere et al study, Bland-Altmann plots were also utilised, however there was no clear range of difference interpretable between the two tools stated, with plots opting to show averages of the two methods and focusing on limits of agreement.[12]

A rough graphical estimation of the range of difference between tools can be found in Figure 2. This graph was generated in order to simplify results and create ease of interpretation. Importantly, no included study made specific comment as to which mode of tonometry yielded the higher results, although this may be loosely assumed from the mean of each instrument as recorded in Table 4.

Whilst four out of the five studies concluded that iCare was comparable enough and reliably similar to Perkins tonometry, some of the studies did include parameters within which their results may be useful. In particular, in the largest study, Badakere et al noted that these results and the small disparity between measurements was only reliable for pressures below 19mmHg.[12] Outside of this range, the study flagged that values between the two methods may become too disparate.[12]

Finally, Martinez-de-la-Casa et al was the only study to present an oppositional position on the comparability of the two tools. For the first time in the present study, results suggested that the two methods of tonometry were not interchangeable. Despite recording only a mean difference of 3.1mmHg, not too far from the other included studies, the authors of this particular study argued that the high variability was considered too unreliable and advised against simply interchanging the two tools.[14]

Whilst being the only study to present a differing position on the interchangeability of the two tonometry methods, it is important to note that Martinez-de-la-Casa et al was the only study to utilise only the original iCare model,[14] and not the PRO model which was adopted by all other studies. In every other study, the iCare PRO model was utilised whilst in the Esmael et al study it was noted that both the original and PRO models were used, however no specific breakdown on the comparability of the two models was made.[15] Further to this, the use of anaesthetic varied amongst studies with only three including patients requiring examination under anaesthesia,[12,13,16] whilst the other two studies favoured local anaesthetic for applanation methods.[14,15] Both of these factors were considered by the authors of the present study when forming conclusions from these results.

In an additional secondary outcome, Mendez-Hernandez et al were able to suggest that the iCare Pro is more comparable to PAT than Tonopen XL, however this was not overtly significant to the present study.[13]

DISCUSSION

Findings

In congenital glaucoma patients, iCare (RBT) may be used as a reliable alternative to the gold standard GAT or PAT. iCare, and its various models, have been found in the included studies as being relatively consistent with PAT, thus rendering it a useful and relatively accurate tool for assessment and management of children with congenital glaucoma. RBT can be used both under sedation and without sedation in outpatient clinics. However, only more recent models of RBT may be usable under sedation as older models do not allow for testing in supine positions.[16]

Table 4. Results of included studies

	Perkins (mmHg)	iCare/Rebound (mmHg)	Difference (mmHg)	iCare vs Perkins
Mendez-Hernandez et al (Spain, 2019)13	Mean = 17.99 SD: +/- 6.24 Range = 2 - 36	Mean = 19.3 SD: +/- 6.10 Range = 6 - 34	Mean = 2.18 SD: +/- 3.45 Range** = -10 - 7 Range^ = 7 - 11 95% CI** = -8.94 to 4.58 p <0.0001	iCare comparable Can interchange (only iCare PRO utilised in this study)
Badakere et al (India, 2019)12	Median = 14 IQR: 11 - 18 Range = 6 - 44	Median = 16 IQR: 13.5 - 20.5 Range = 6.2 - 39	Mean = 2 SD: * Range = * 95% CI = -5.4 to 9.4 p <0.001	iCare comparable Can interchange (only iCare PRO utilised in this study)
Esmael et al (Egypt, 2019)15	Mean = * SD: * Range = *	Mean = * SD: * Range = *	Mean = -0.79 SD: +/- 2.83 Range** = -6 - 6 95% CI = -6.34 to 4.76 p = 0.032	iCare comparable Can interchange (two models of iCare used, including PRO)
Borrego Sanz et al (Spain, 2016)16	Mean = 18.12 SD: +/- 4.89 Range = 10 - 28	Mean = 18.54 SD: +/- 5.38 Range = 8.3 - 29.1	Mean = 0.42 SD: +/- 3.69 Range** = -6 - 9 95% CI = -6.8 to 7.7 p = 0.41	iCare comparable Can interchange (only iCare PRO utilised in this study)
Martinez-de-la-Casa et al (Spain, 2009)14	Mean = 19.1 SD: +/- 5.4 Range = 10 - 37	Mean = 22.1 SD: +/- 7.7 Range = 9 - 40	Mean = 3.1 SD: +/- 4.0 Range** = -3 - +15 95% CI = -4.8 to 10.9 p <0.0001	iCare not comparable Variance too high, may be due to various factors (eg corneal factors). Requests further research in area (only original iCare model utilised)

* = number not provided, ** = interpreted from Bland-Altmann plot, CI = confidence interval, P = p value, IQR = interquartile range, ^ = range of mean difference. Note: Range presented in this table is the range of difference between the two tools, not range of mean differences. 95% CI was recorded for level of agreement, not 95%CI of means.

In all but one of the included studies, iCare was deemed comparable to PAT when IOP remained below 19mmHg. Once IOP increased, the interval of difference between the tools varied significantly. Whilst some studies did comment on this variance, multiple others did not. With the inconsistencies of these results, it can be suggested that iCare is relatively reliable in most cases, however to err on the side of caution one should confirm higher pressures with a more reliable tool such as PAT, as suggested by Badakere et al.[12]

For the opposing study, Martinez-de-la-Casa et al presented the notion that PAT cannot be simply interchanged for RBT due to the high variability of results, thus causing some uncertainty in this review.[14] The authors did suggest that the variability may be

due, at least in part, to corneal factors. Thus, it is the suggestion of the present study that rather than deeming iCare unreliable in all congenital glaucoma patients, this is rather a cautionary tale to practitioners when managing congenital glaucoma patients or suspects with other comorbidities. Other ocular factors, such as axial length, must also be considered in the analysis of results, as suggested by various included studies.

Unlike the other studies, Martinez-de-la-Casa et al employed a further interesting measurement, an 'ease of use' scale.[14] A secondary outcome was analysed as to whether practitioners preferred to use RBT or PAT. The results of this highlighted that practitioners did prefer iCare (7.9 +/- 0.7 vs PAT 6.4 +/- 1.7), suggesting that it would be an easy endeavour to further implement iCare into paediatric clinics. The results of this one investigation, although limited, confirm to the present study that iCare is both relatively reliable and can increase the ease of measurement in potentially unsettled children.

It is important to note that the present study was unable to include any literature regarding comparability to GAT. One study fell just short of the included age range, yet it suggested, like Martinez-de-la-Casa et al, that iCare was not comparable to Goldmann.[18] As such perhaps the use of RBT must be further analysed in older populations or in its comparison to the true gold standard GAT.

Furthermore, no included study focused on congenital glaucoma suspects. Due to the dependence on IOP measurement for diagnosis of congenital glaucoma, the present study is reluctant to assert whether RBT is useable in diagnosis. Rather, it would be in the best interest of clinical decisions that further research is done on the suspect population and whether RBT can aid diagnosis. Thus, the present study will only suggest that iCare is comparable enough to PAT to be interchanged in congenital glaucoma patients, however at higher pressures and when diagnosing suspected glaucoma, a more reliable tool such as PAT should be utilised and further research into suspects is indicated.

Strengths and limitations

The strengths of the review lie in the fact that two independent researchers, who have no stake in the outcomes, conducted a search of several reliable databases for the review.

Nonetheless, there are some limitations regarding the vigour of the results. For instance, only five papers were included in the review, the majority of which had a relatively low sample size, with Badakere et al having the largest sample consisting of 106 individuals.[12] As a direct consequence, the results may not be as reliable as they may not be repeatable in larger sample sizes and thus may be less applicable to society in a broader sense.

Additionally, the studies were also limited by the English language, which excluded two papers, which could have provided further support or contradiction to the results gathered.

Individual papers also noted their own limitations. Mendez-Hernandez et al reiterated that their study was limited by the small number of participants, which was impacted by the fact that congenital glaucoma is an infrequent disease.[13] Furthermore, Borrego Sanz et al affirmed this by noting that further studies with larger sample sizes are required to confirm correlation between devices.[16]

Furthermore, another limitation noted in the individual studies is the effect of sedation on intraocular pressure. Borrego Sanz et al and Esmael et al both agreed that anaesthetic showed an apparent IOP-lowering effect, which should be cautiously studied in future research.[15,16] Additionally, Martinez-de-la-Casa et al raised another variable affecting reliability, by denoting that modified corneal characteristics in PCG patients such as corneal hysteresis and corneal resistance factor may account for discrepancies.[14]

Overall, based on these limitations, recommendations would be that future studies should be conducted utilising larger sample sizes. Also, research needs to be conducted on the impact of sedation, corneal state and comorbidities on intraocular pressure readings.

Contextualising the findings

Lambert et al offered similar clinical findings, suggesting that iCare may be substituted for GAT or PAT in both healthy children and those with congenital glaucoma.[8] Despite publication of their results, a study in the UK found that iCare is not readily available.[17] Chan et al reported that less than 15% of clinics had iCare, despite acknowledging that IOP measurement is 'crucial in the assessment of paediatric glaucoma' and GAT was 'unpractical'.[17] It is perhaps due to this lack of availability that iCare has not been adopted widely in congenital glaucoma assessment. However, iCare is increasing its availability, having been FDA approved in Canada and Europe since 2013.[16]

Furthermore, in both literature and many clinics, Goldmann, or PAT, in children is still acknowledged as the gold standard. Whilst some clinics have pivoted to RBT, substantial literature and common practices do not support this decision. In many clinics, it may be deemed 'close enough', however if it should become more popular, literature needs to support this. Although RBT may never be the gold standard, it still requires support from research to validate the actions of clinicians, as was the aim and outcome of this review.

CONCLUSION

In future clinical practice, following the results of this review, it is hoped that iCare will provide a simpler and easier way to measure IOP in children suffering from congenital glaucoma. To improve clinical efficiency and reduce the need for EUA, which may be deemed difficult for children, iCare will hopefully be adopted by more clinicians, become more readily available and supported by literature.

Whilst this review had strict exclusion criteria and focused on children with only congenital glaucoma or suspects, further study must be conducted into the effects of corneal state, axial length and other ocular elements. The included studies did mention that other ocular comorbidities may affect the reliability of RBT, however this was not the focus here. If variations do occur, they must be studied for the applicability in those cases and applied accordingly.

ACKNOWLEDGEMENTS

The authors of this study would like to acknowledge Dr Meri Vukicevic and Linda Santamaria for their assistance in finalising this article and encouraging well-considered amendments to the work.

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