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ORIGINAL ARTICLE

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Utility of incomplete right bundle branch block as an isolated ECG finding in children undergoing initial cardiac evaluation

Omar Meziab MD | Dominic J. Abrams MD | Mark E. Alexander MD | Laura Bevilacqua MD | Vassilios Bezzerides MD | Doug Y. Mah MD | Edward P. Walsh MD | John K. Triedman MD

Boston Children's Hospital, Boston, Massachusetts, USA

Correspondence
Omar Meziab, MD, 36 Park Street Apt 4, Brookline, MA 02446, USA.
Email: omar.meziab@childrens.harvard.edu

Abstract

Objective: This study evaluates the ability of experienced pediatric electrophysiologists (EPs) to reliably classify incomplete right bundle branch block (IRBBB) and assesses its clinical utility as an isolated ECG finding in a group of healthy outpatient children without prior cardiac evaluation.

Design: We performed a retrospective analysis of all electrocardiographic and echocardiographic records at Boston Children's Hospital between January 1, 2005, and December 31, 2014. Echocardiographic diagnoses were identified if registered between the date of the index electrocardiogram and the ensuing year. A selected subset of 473 ECGs was subsequently reanalyzed in a blinded manner by six pediatric EPs to determine the consistency with which the finding of IRBBB could be assigned.

Results: Of the 331 278 ECGs registered in the BCH database, 32 127 (9.7%) met inclusion criteria and were analyzed for the prevalence of isolated right bundle conduction disturbance findings. The mean age was 12.1 ± 4.0 years, and the population was 49% male. Of the 32 127 ECGs, 72.5% were coded normal, 3.0% were coded IRBBB, and 0.5% were coded complete right bundle branch block (CRBBB). A total of 7.3% of patients coded as normal had an ensuing echocardiogram, compared to 12.5% coded IRBBB. Echo findings were recorded in 0.1% of normal and 0.2% of IRBBB. Patients with ASD-secundum type were no more likely to have isolated IRBBB on previous ECG than the general population (2.5% vs 3.0%). Analysis of inter-reader variability in ECG findings and conduction disturbance identification was high (range of IRBBB prevalence 1-20% among readers). Reinterpretation of ECGs using explicit diagnostic criteria did not demonstrate consistent discrimination of IRBBB and Normal ECGs.

Conclusions: IRBBB is not uncommon in a healthy school age population and is observed to have high inter-reader variability. It was associated with increased use of echocardiographic exam but was not associated with increased rate of echocardiographic findings when compared with rates for normal ECGs.

KEYWORDS

clinical significance, electrocardiogram, incomplete right bundle branch block, pediatric, RSR′

1 | INTRODUCTION

Screening by electrocardiogram (ECG) is increasingly used to evaluate children without known heart disease prior to initiation of various classes of medication, participation in competitive sports, and surgical procedures. Although several sets of major criteria for increased risk of significant heart disease have been proposed,[1–3] minor electrocardiographic findings are considerably more common and of uncertain significance and sometimes cause considerable concern.

Incomplete right bundle branch block (IRBBB) is commonly identified in pediatric ECGs.[4–10] Though it is frequently noted, the criteria used to define IRBBB vary with respect to QRS duration, morphology, and age dependence of parameters.[1–3] Even when standard criteria are available, the ability of even experienced practitioners to consistently apply them to the identification of pediatric ECG findings is imperfect.[11–13] Thus, there is likely to be considerable latitude in the discrimination of a finding of IRBBB from patients with normal ECGs and conversely those with complete right bundle branch block (CRBBB).

While IRBBB is prevalent, its significance as a finding in a previously healthy child has also not been demonstrated. IRBBB may be observed in some patients with known atrial septal defect (ASD), but it may not be associated with ASD in a predictively useful way.[14–18] It may also be a dynamic ECG finding in those with the rare but important ion channel defect Brugada syndrome.[19]

To determine the predictive utility of IRBBB as an isolated ECG finding, we sought to answer the following questions. First, what is the prevalence of IRBBB and CRBBB compared to "normal" ECGs in an outpatient population of children receiving their first ever ECG at our institution? Second, what additional diagnostic evaluation followed an initial observation of either IRBBB or CRBBB and what is the prevalence of subsequently diagnosed anatomical heart disease in these three patient groups? Third, what is the prevalence of IRBBB in patients with known ASD? Finally, what is the consistency with which a group of expert pediatric electrophysiologists is able to reliably classify an isolated finding of IRBBB?

2 | METHODS

Data on 12-lead ECGs taken from pediatric patients at Boston Children's Hospital in Boston, Massachusetts, between January 2005 and December 2014 was collected from an internal database. Population parameters (Figure 1) for study inclusion were applied to this collection of ECGs, including the following: (1) patient age range of 4–18 years; (2) no prior known history of cardiac disease, defined as absence of any record of prior ECG (dating back to January 2000); (3) ECG collected from outpatient clinic or emergency department; and (4) ECG read by a specialist in pediatric electrophysiology with cumulative experience of over 9000 ECG reads during the study period. Assignment of ECGs to these individual readers has historically been made by calendar duty rotation and is thus assumed to be effectively random. In order to further limit this population to patients unlikely to be referred for evaluation of previously known heart disease, patients were then limited to ZIP code of area within ~80 miles of Boston, Massachusetts (014xx-030xx) and those with any prior history of echocardiographic examination were identified and removed. From this group, those patients with isolated ECG findings of "tracing within normal limits" and/or "sinus arrhythmia" (classified for this study as normal), IRBBB, or CRBBB were the targets of study.

The prevalence rates of each category of ECG finding (normal, IRBBB, and CRBBB) were demonstrated. From these subsets, it was determined how many ECGs in each category had an echocardiogram performed within 1 year after the ECG. Furthermore, it was determined how many of these subsequent echocardiograms resulted in a non-normal finding. Further analyses were done to identify ECG reader use of QRS duration as a differentiating feature for interpretation.

During the same time period and from the same limited group, 163 patients were identified as having secundum-type ASD on echocardiogram. The first ECG from the year preceding echocardiographic diagnosis was evaluated for isolated IRBBB diagnosis.

From the total inventory of studies, 473 ECGs (each previously coded as normal, IRBBB, or CRBBB in the 10-year sample) were randomly selected, de-identified and assigned to six current board-certified pediatric cardiologists with a full time electrophysiology practice to be read again. The readers were instructed to provide a new designation of normal, IRBBB, or CRBBB to each ECG based on criteria explicitly

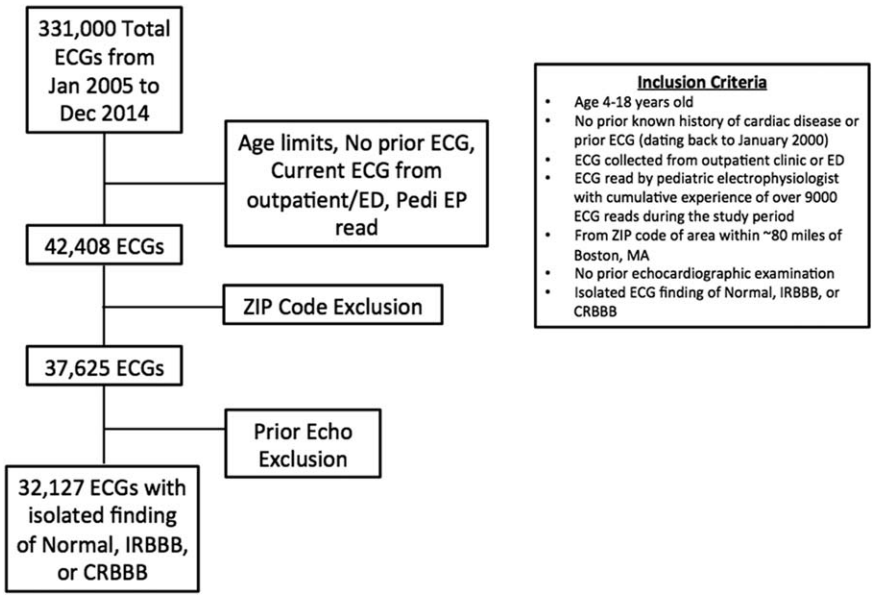

FIGURE 1 Inclusion criteria list—population characteristics

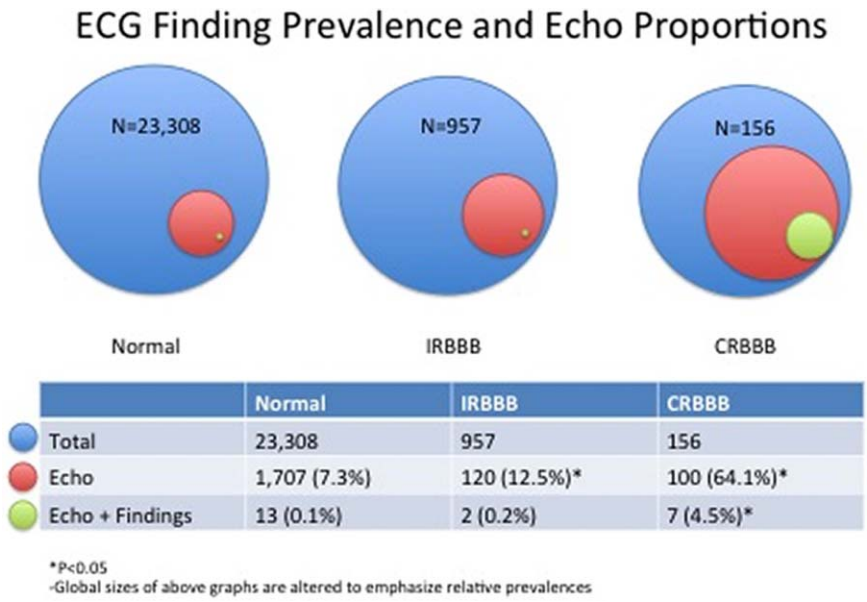

FIGURE 2 Graphical rep of prevalence values over 10 years

provided at the top of each ECG. IRBBB and CRBBB criteria were constructed based on simplified existing parameters gathered from the American Heart Association, Seattle Criteria, and World Health Organization. Finalized IRBBB criteria included as follows: (1) QRS duration less than 110 ms, (2) terminal R wave in V1, and (3) wide terminal S wave in leads I and V6. CRBBB was defined as meeting the same criteria as IRBBB except for having QRS duration of greater than 110 ms.

The ECG readers designated each ECG as one of normal, IRBBB, or CRBBB. After completion, the total number of ECG designations of each reviewer were evaluated and compared. For an ECG with complete agreement among the reviewers, a classification of "consensus" was applied. For ECGs with agreement among five of the six reviewers, a classification of "agreement" was applied. For ECGs with agreement among four reviewers, a classification of "classifiable" was given. ECGs with agreement among a maximum of three reviewers were classified as "unclassifiable." Each ECG was assigned a final designation of normal, IRBBB, or CRBBB based on a majority of agreement of the composite evaluations of the six reviewers. Percentage of consensus designations for normal, IRBBB, and CRBBB was evaluated and compared to expected percentages using chi-square testing. Additionally, quality of disagreement was evaluated, with tallying of which nonconsensus designations were given to each ECG (ie, an overall "agreement" ECG designated as IRBBB having the lone dissenting reader grade it as being normal). The total number of dissenting responses was gathered, and the percentages of likelihood of confusing IRBBB/CRBBB and IRBBB/normal were evaluated.

Finally, the ECG designations of each reader were compared against those of each other reader to evaluate for inter-rater consistency in interpretation. Their results were initially compared head to head and assigned kappa coefficients for individual comparisons between two readers. The consistency of ECG designations was then evaluated as a group using Fleiss' kappa coefficient.

3 | RESULTS

3.1 | Prevalence of normal, isolated IRBBB, and isolated CRBBB findings and association with echocardiographic diagnoses

The grand total of ECGs signed during the study period was 331 278. A subset of 42 408 total pediatric ECGs were identified which qualified for inclusion in this study based on the parameters outlined above (Figure 1). Of this total, 20 796 (49%) were from male subjects. The subjects' mean age was 12.1 ± 4.0 years. Of the entire set of first time ECGs, 37 625 of these were from patients living within ZIP codes within ~80 miles of Boston city limits. There were 35 684 first-time ECGs in patients who had not had an echocardiogram done prior to the identified ECG. When eliminating subjects living out of the ZIP code designation and with prior echocardiograms, the final set of patients with first-time ECGs was 32 127 (9.7% of total ECGs).

A total of 23 308 (72.5%) of the final set of ECGs were read as normal, 957 (3.0%) were read as having IRBBB, and 156 (0.5%) were read as having CRBBB. The total number of first-time ECGs with subsequent echocardiograms in the ensuing year was 2386 (8.8% of all ECGs). Of the normal ECGs, 1707 (7.3%) of them were followed by an echocardiogram. IRBBB ECGs were followed by 120 (12.5%) echocardiograms, while CRBBB ECGs were followed by 100 (64.1%) echocardiograms. By Fisher's exact testing, there was a significantly higher number of echocardiograms performed for IRBBB when compared with normal ECGs ($P < .05$), as well as for CRBBB when compared with normal ECGs ($P < .05$). The total number of first-time ECGs with any nonnormal echocardiogram diagnoses was 85 (0.3% of all ECGs). Of the normal ECGs, 13 (0.1%) of them were followed by a nonnormal echocardiographic diagnosis. IRBBB ECGs lead to 2 (0.2%) echocardiograms with nonnormal diagnoses, while CRBBB

TABLE 1 Interobserver rates of ECG designation 2005–2014

Observer	Normal (%)	IRBBB (%)	CRBBB (%)
1	73	5	0.7
2	70	3	0.4
3	78	1	0.5
4	62	3	0.7
5	57	3	0.1
6	86	1	0.5
7	73	4	0.3
8	54	20	0.4
Mean	72.5	3.0	0.5
Coefficient of variability	1.6	12.9	0.1

ECGs were followed by seven nonnormal echocardiograms (4.5%). By Fisher's exact testing, there was no significant difference in the number of nonnormal echocardiogram findings for IRBBB compared to normal ECGs ($P = .26$). There was a significant difference in the number of nonnormal echocardiogram findings for CRBBB compared to normal ECGs ($P < .05$). All numerical analyses are listed and graphically represented in Figure 2.

3.2 | Previous ECG findings in patients with ASD

Over the study period, 163 patients were identified with isolated secundum-type ASD on echocardiogram. Their mean age was 8.7 ± 4.4 years. Of them, seven had a first time ECG during the preceding year with a finding of IRBBB. That group included four patients with isolated findings of IRBBB on first ECG, showing a prevalence of 2.5% of isolated findings of IRBBB on ECG in patients with known isolated secundum-type ASD.

3.3 | Evaluation of discrimination of ECG findings

In the initial collection of ECGs read from 2005 to 2014, the group of readers varied in their respective proportions of identified readings of normal, IRBBB, and CRBBB (Table 1). The total percentage of ECGs identified as normal was 72.5, with the lowest percentage by an individual reader being 54 and the highest percentage being 86. This accounted for an absolute difference of 32% with a relative difference 1.59 times higher in the upper value, with a coefficient of variability of 1.6%. The total percentage of ECGs identified as IRBBB was 3.2, with the lowest percentage by an individual reader being 1 and the highest percentage being 20. This accounted for an absolute difference of 19% with a relative difference 20 times higher in the upper value, with a coefficient of variability of 12.9%. The total percentage of ECGs identified as CRBBB was 0.5, with the lowest percentage by an individual reader being 0.1 and the highest percentage being 0.7. This accounted for an absolute difference of 0.6% with a relative difference 7 times higher in the upper value, with a coefficient of variability of 0.1%.

The QRS distribution histograms in Figure 3 demonstrate this variance, with IRBBB and CRBBB QRS durations varying widely among readers. The average QRS duration used as the transition point between IRBBB and CRBBB for each reader varied by 15 ms, while the percentage of overlap of QRS durations among readers in distinguishing between IRBBB and CRBBB ranged from 14 to 67. The average of the median QRS durations from ECGs identified by any reader as Normal from the original set was 82 ms. The average median QRS duration of IRBBB designated ECGs from the original set was 89.5 ms, while the value for CRBBB designated ECGs was 130.5 ms (Table 2). The average of the median QRS durations from ECGs identified by any reader as IRBBB from the reexamined set was 96.7 ms, while the average median QRS duration of CRBBB designated ECGs was 130 ms.

Upon reexamination by the 6 EP readers using the constructed definitions, 247 (52.2%) were identified as normal, 76 (16.1%) were

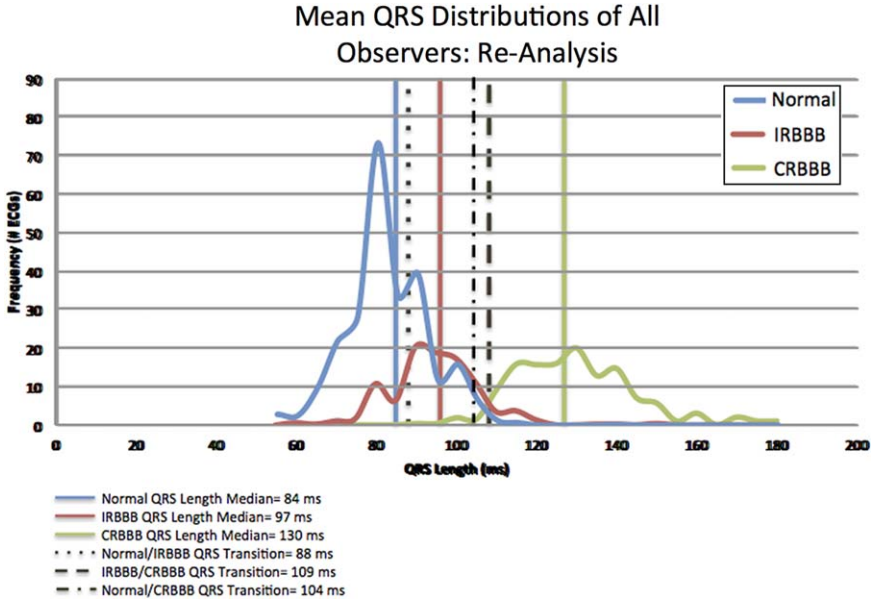

FIGURE 3 Histograms from reanalysis

TABLE 2 Mean QRS distributions of all observers: 2005–2014

	QRS length (ms)
Normal median	82
IRBBB median	89.5
CRBBB median	130.5
	QRS transition point (ms)
Normal/IRBBB	81
IRBBB/CRBBB	108

identified as having IRBBB, and 128 (27.1%) were identified as having CRBBB (Table 3). Based on previous ECG readings, the expected distribution was 35.2% normal, 34.4% IRBBB, and 30.4% CRBBB. By Fisher's exact multinomial testing, this finding was found to be significant ($P < .001$). Furthermore, 22 (4.7%) of the reread ECGs were given no consensus classification, as there was not a majority designation provided by the group of readers.

When looking at all 323 ECGs determined by majority of reviewers to be normal or IRBBB, there were 153 instances of a reader making the nonmajority designation of that ECG. After accounting for six total reviewers, these total values result in a rate of 7.9% crossover of designations of Normal and IRBBB. When looking at all 204 ECGs determined by majority of reviewers to be IRBBB or CRBBB, there were 34 instances of a reader making the nonmajority designation of that ECG. After accounting for six total reviewers, these total values result in a rate of 2.8% crossover of designations of IRBBB and CRBBB. The relative increased likelihood of confusing Normal and IRBBB compared to confusing IRBBB and CRBBB was 2.8. Kappa coefficients for 15 pairwise comparisons between readers ranged from 0.67 to 0.83 (Table 4A). The Fleiss' kappa coefficients for inter-rater reliability by diagnostic category were 0.76 for normal ECGs, 0.55 for IRBBB, and 0.91 for CRBBB (Table 4B).

TABLE 4 Reanalysis interobserver agreement

(A) Pairwise interobserver kappa values						
Observer	**1**	**2**	**3**	**4**	**5**	**6**
1	1	0.71	0.69	0.68	0.67	0.68
2		1	0.75	0.82	0.79	0.83
3			1	0.76	0.78	0.81
4				1	0.77	0.82
5					1	0.79
6						1

(B) Group kappa values			
	Normal	**IRBBB**	**CRBBB**
Kappa	0.76	0.55	0.9l

Kappa interpretation[20]:
Moderate agreement = 0.41–0.60.
Substantial agreement = 0.61–0.80.
Near perfect agreement = 0.81–1.00.

4 | DISCUSSION

In this study, we examined a large population of school-aged children from areas surrounding Boston with a first time ECG done in an outpatient setting. This population was chosen to be similar to a general population of children presenting for screening ECG. Our primary findings were as follows. First, although the isolated finding of IRBBB was roughly twice as likely as Normal patients to undergo a subsequent echocardiogram, the rate of anatomical findings in both populations was similar and exceedingly low. Second, the prevalence of IRBBB in patients from this group found to have an ASD was not different from the group as a whole. Third, when experienced pediatric EPs were given explicit criteria for distinguishing normal, IRBBB and CRBBB findings, there remained considerable discrepancy in assignment of findings and extensive confusion between normal and IRBBB ECGs.

Patients were most commonly found to have normal ECGs (72.5%), with isolated IRBBB an infrequent finding (3.0% of all ECGs) and isolated CRBBB only rarely (0.5%) identified. Compared to published studies, the prevalence of IRBBB in our population was within previously observed ranges.[4–10] This prevalence varies widely depending on the population examined[6,7,10,21] and other ECG findings incorporated with it.[10,21]

A potential association has been suggested between IRBBB and atrial septal defect (ASD), a cardiac defect with low prevalence in healthy populations of children not otherwise known to have heart

TABLE 3 Interobserver rates of ECG designation upon reanalysis

Designation	Number	Observed (%)	Expected (%)	Expected total
Normal	247	52.2	35.2	167
IRBBB	76	16.1	34.4	163
CRBBB	128	27.1	30.4	144
Unclassifiable	22	4.7	0.0	0
Grand total	473	100	100	473
$P < .0001$				

Classification	Consensus—6/6	Agreement—5/6	Classifiable—4/6	Unclassifiable—<4/6
Number (%)	310 (65)	93 (20)	48 (10)	22 (5)

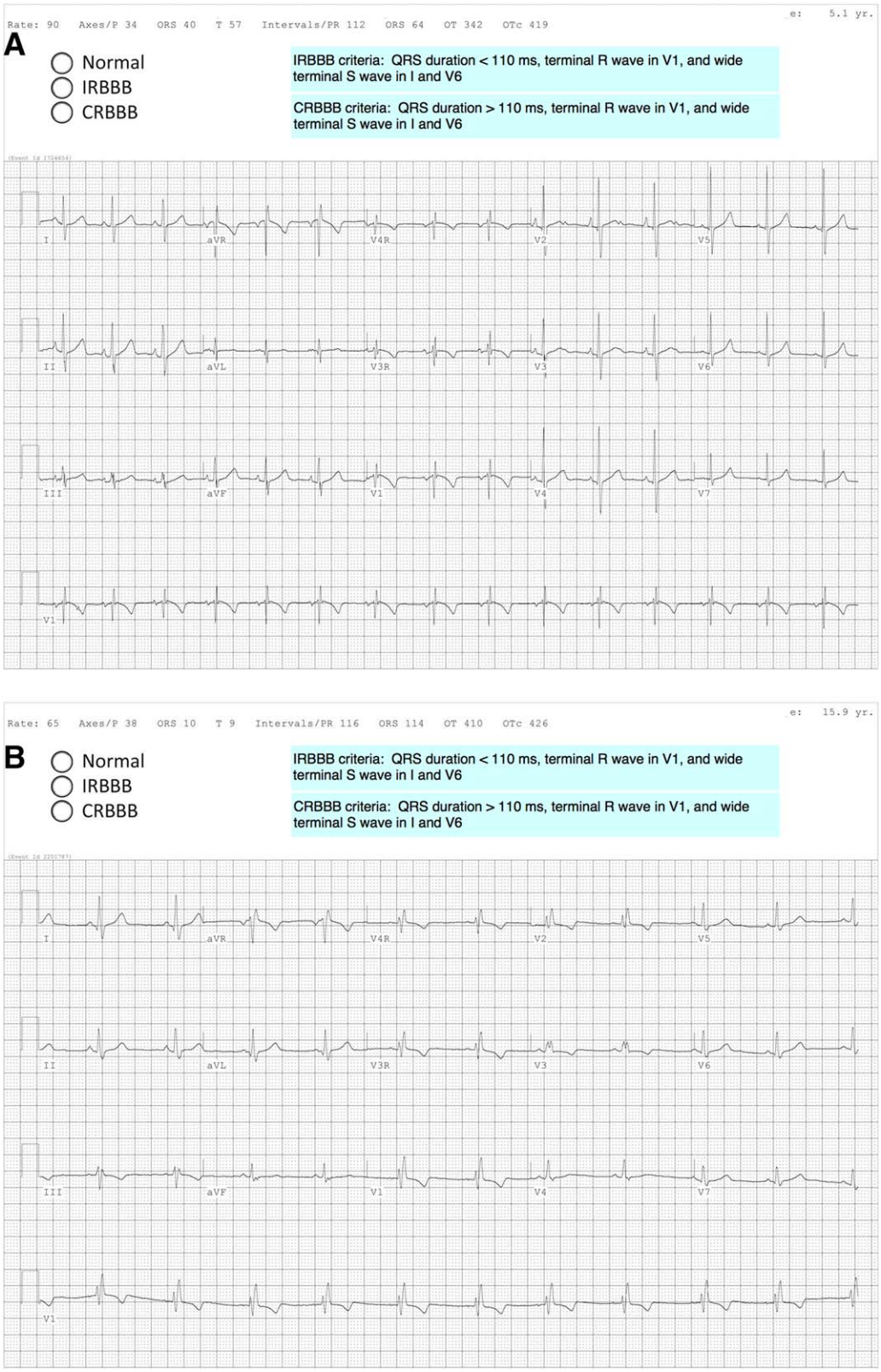

FIGURE 4 (A-C) Reanalysis ECG examples

disease.[16,22–26] This observation may suggest to clinicians that the presence of IRBBB in itself indicates the need for further anatomical evaluation. However, this association has not demonstrated great predictive value for finding ASD in other reviews.[15,16,27] Patients with isolated IRBBB in our group were almost twice as likely as normal ECGs to have an echocardiogram performed within the year following the ECG (12.5% vs. 7.3%), but these echocardiograms resulted in non-normal findings at proportionally similar rates for both IRBBB and

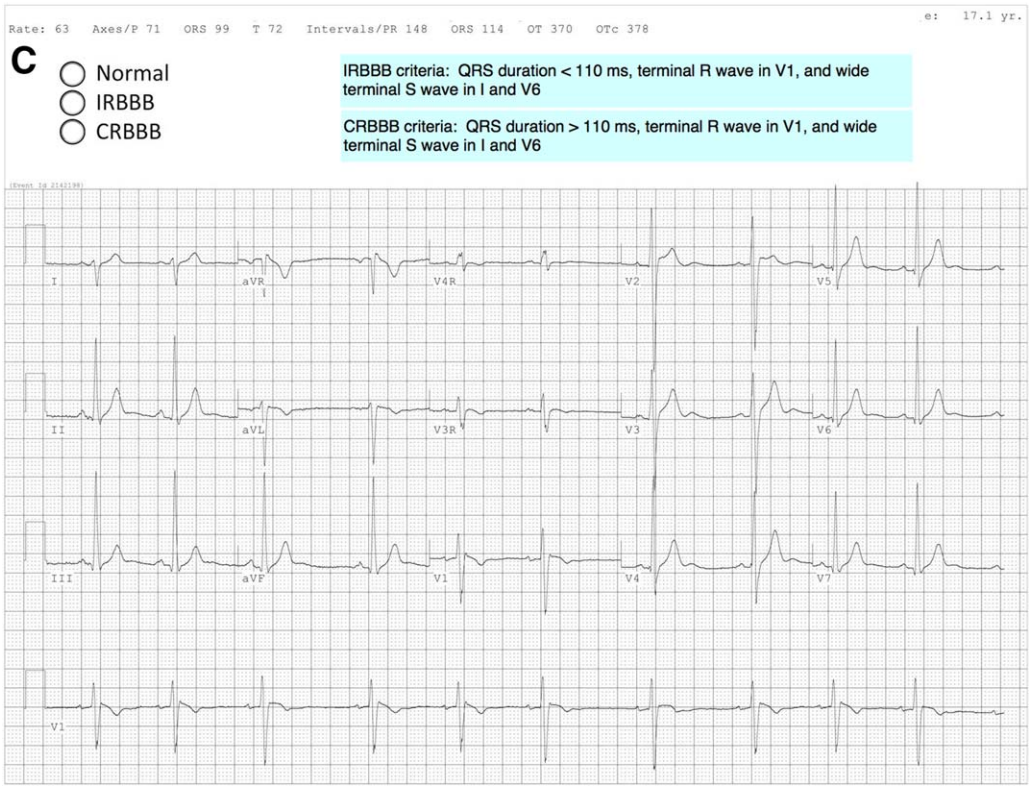

FIGURE 4 (Continued)

normal ECGs. This is corroborated by our further observation that there was no increase in prevalence of IRBBB in patients with ASD (2.5%) compared to the general study population (3.0%).

As mentioned earlier, multiple sets of diagnostic criteria have been proposed for determination of IRBBB and CRBBB in children.[1–3] If ECG readers use varying rules to assign these findings, it weakens any specific associations with cardiac disease that may actually be present. It is possible that this variability could be reduced and predictive power increased by applying a single common set of criteria for IRBBB. In our initial study set, there was marked variability in the proportions with which different pediatric EPs assigned the findings of normal, IRBBB, and CRBBB (Table 1), as well as an outlier (Observer 8). This indicates a lack of uniformity in ECG interpretation, despite the fact that the readers are trained in cardiac arrhythmia and reading a high volume of randomly assigned tracings. This observation was particularly also reflected in the differing distributions of QRS duration between readers. This data suggests that, although QRS duration has been emphasized as a major distinguishing factor between IRBBB and CRBBB in all published guidelines, expert ECG readers do not consistently employ this distinction and/or utilize other criteria to assign these diagnostic findings in practice.

Although there are multiple definitions of IRBBB and CRBBB that could lead to confusion, they do overlap considerably. Previous studies have questioned the dependability and consistency of pediatric cardiologist-read ECGs as a screening tool when tested against a "gold standard."[11,12] However, we considered that consistent adherence to a single set of rules by the ECG readers could mitigate variability in reading. To better understand the question of consistency and evaluate for ECG interpretation rule adherence, a sample group of ECGs was collected from the database, de-identified and redistributed to pediatric EPs for blinded analysis, with provision of specific grading criteria written on each ECG (Figure 4A–C). Despite this, readers reached effective diagnostic consensus (agreement among at least five of the six readers) on the coding of these ECGs in only 85% of cases. During re-examinations, readers classified more tracings than expected as normal ECGs, and were more likely to confuse normal and IRBBB ECGs than they were to confuse IRBBB and CRBBB ECGs. Agreement among the readers was rated as "substantial" to "near-perfect" based on pairwise kappa coefficient analysis and in total for normal and CRBBB ECGs, but only as "moderate" agreement amongst readers regarding IRBBB identification. Almost complete overlap in QRS duration was noted between ECGs coded as normal and those coded as IRBBB.

Our data suggest that even with emphasis of a uniform definition of IRBBB, skilled readers remain inconsistent in their discrimination between normal and IRBBB, a previously discussed finding.[13,21] The initial historical variability that was noted in our evaluation of ECGs read over a ten year window was only marginally decreased by providing a standardized criteria for guiding blinded rereading of a selected subsample of normal, IRBBB, and CRBBB ECGs (Tables 3 and 4A and B). This is similar to marginal improvement in ECG classification previously demonstrated with instructional remediation with respect to screening criteria.[28] Stated simply, providing uniform ECG criteria for IRBBB and CRBBB did not substantially correct the ability of skilled ECG readers to differentiate normal and IRBBB coding of ECGs.

4.1 | Limitations

In the retrospective portion of this study, high-volume, expert ECG readers, working under clinical conditions, are assumed to represent a "gold standard" for accuracy and reproducibility. This assumption of a gold standard defined in this way is challenged by the findings of the study itself, which indicate significant variability and the importance of "style" of interpretation, even in expert readers. Structured reanalysis of ECGs was performed to determine whether this variability was due to inconsistent understanding of a single, simple set of criteria for IRBBB, and in this process, group consensus was used to determine the "correct" finding within an ECG, in the absence of a set definitive answer. Although it can be asserted that the criteria themselves represent a "gold standard," our data indicate that such "standards" cannot in fact be applied to clinical practice.

Though considerable focus was placed on eliminating previously known cardiac patients, there is the possibility that these patients could creep in to the data set and be responsible for some number of echocardiograms and echo findings. Enumeration of echocardiographic finding was dependent on prior clinical readings from other practitioners.

The kappa coefficient statistic is not universally accepted as a perfect measurement and its scoring thresholds for reliability grading are largely arbitrary, though for this analysis it was just used as a general gauge of inter-reader reliability.

5 | CONCLUSION

The results of this study call attention to and question the value of the isolated electrocardiographic finding of IRBBB in healthy children. This frequently used finding is loosely based on multiple nonunified diagnostic criteria established over different time periods. Our analysis showed that multiple experienced observers were inconsistent in their ECG interpretation of IRBBB, even when directly provided diagnostic criteria. Equally important, a finding of IRBBB in this population of patients was found to be associated with no clinically significant new diagnoses over a ten-year study period, although it did appear to result in an increased utilization of diagnostic imaging. The diagnostic utility of isolated IRBBB in ECG of school age children in and of itself is therefore limited both by difficulty in its application as well as its lack of diagnostic specificity, and it should not be considered an indication for further evaluation.

CONFLICT OF INTEREST

None of the authors of this article have any conflicts of interest or funding to disclose pertaining to the content of this article.

AUTHOR CONTRIBUTIONS

Design, data analysis/interpretation, and drafting article: Meziab
Approval of article: Abrams
Critical revision of article: Alexander
Approval of article: Bevilacqua
Approval of article: Bezzerides
Approval of article: Mah
Critical revision of article: Walsh
Design, data analysis/interpretation, and critical revision of article: Triedman

ORCID

Omar Meziab MD http://orcid.org/0000-0003-1196-0974

REFERENCES

[1] Willems JL, Robles de Medina EO, Bernard R, et al. Criteria for intraventricular conduction disturbances and pre-excitation. *JACC*. 1985;5(6):1261–1275.

[2] Surawicz B, Childers R, Deal BJ, et al. Standardization and Interpretation of the ECG, part III. *JACC*. 2009;53(11):976–981.

[3] Drezner JA, Fischbach P, Froelicher V, et al. Normal electrocardiographic findings: recognising physiological adaptations in athletes. *Br J Sports Med*. 2013;47(3):125–136.

[4] Chiu SN, et al. Cardiac conduction disturbance detected in a pediatric population. *J Pediatr*. 2008;152(1):85–89.

[5] Kobza R, Cuculi F, Abächerli R, et al. Twelve-lead electrocardiography in the young: physiologic and pathologic abnormalities. *Heart Rhythm*. 2012;9(12):2018–2022.

[6] Langdeau JB, et al. Electrocardiographic findings in athletes: the prevalence of left ventricular hypertrophy and conduction defects. *Can J Cardiol*. 2001;17(6):655–659.

[7] Le V-V, Wheeler MT, Mandic S, et al. Addition of the electrocardiogram to the preparticipation examination of college athletes. *Clin J Sport Med*. 2010;20(2):98–105.

[8] Niwa K, Warita N, Sunami Y, et al. Prevalence of arrhythmias and conduction disturbances in large population-based samples of children. *Cardiol Young*. 2004;14(01):68–74.

[9] Pelliccia A, Culasso F, Di Paolo FM, et al. Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening. *Eur Heart J*. 2007;28(16):2006–2010.

[10] Sharma S, Whyte G, Elliott P, et al. Electrocardiographic changes in 1000 highly trained junior elite athletes. *Br J Sports Med*. 1999;33(5):319–324.

[11] Harbison AL, Hill AC, Motonaga KS, et al. Do pediatric electrophysiologists read pre-participation screening electrocardiograms more accurately than general pediatric cardiologists? *J Pediatr*. 2013;163(6):1775–1777.

[12] Hill AC, Miyake CY, Grady S, et al. Accuracy of interpretation of preparticipation screening electrocardiograms. *J Pediatr*. 2011;159(5):783–788.

[13] Zhou SH, Liebman J, Dubin AM, et al. Using 12-lead ECG and synthesized VCG in detection of right ventricular hypertrophy with terminal right conduction delay versus partial right bundle branch block in the pediatric population. *J Electrocardiol*. 2001;34(suppl):249–257.

[14] Blount SG, Munyan EA, Hoffman MS, et al. Hypertrophy of the right ventricular outflow tract: a concept of the electrocardiographic findings in atrial septal defect. *Am J Med*. 1957;22(5):784–790.

[15] Matoba M, et al. Management of incomplete right bundle-branch block in heart disease screening program. *Jpn J Pediatr*. 1987;50:1220–1224.

[16] Muta H, Akagi T, Egami K, et al. Incidence and clinical features of asymptomatic atrial septal defect in school children diagnosed by heart disease screening. *Circ J*. 2003;67(2):112–115.

[17] Sung RJ, Tamer DM, Agha AS, et al. Etiology of the electrocardiographic pattern of "incomplete right bundle branch block" in atrial septal defect: an electrophysiologic study. *J Pediatr*. 1975;87(6):1182–1186.

[18] Wang NK, Shen CT, Lin MS. Results of echocardiographic screening in 10,000 newborns. *Acta Paediatr Taiwan*. 2007;48(1):7–9.

[19] Probst V, Allouis M, Sacher F, et al. Progressive cardiac conduction defect is the prevailing phenotype in carriers of a Brugada syndrome SCN5A mutation. *J Cardiovasc Electrophysiol*. 2006;17(3):270–275.

[20] Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–174.

[21] De Asmundis C, Conte G, Levinstein M, et al. Prevalence and electrocardiographic characteristics of early repolarization pattern in young teen athletes. *Acta Cardiol*. 2014;69(1):3–6.

[22] Hoffman JI, Kaplan S. The incidence of congenital heart disease. *J Am Coll Cardiol*. 2002;39(12):1890–1900.

[23] Kang G, Xiao J, Wang J, et al. Congenital heart disease in local and migrant elementary schoolchildren in Dongguan, China. *Am J Cardiol*. 2016;117(3):461–464.

[24] Reller MD, Strickland MJ, Riehle-Colarusso T, et al. Prevalence of congenital heart defects in metropolitan Atlanta, 1998–2005. *J Pediatr*. 2008;153(6):807–813.

[25] Wang MX, et al. Defective T wave combined with incomplete right bundle branch block: a new electrocardiographic index for diagnosing atrial septal defect. *Chin Med J*. 2012;125(6):1057–1062.

[26] Zhang Y, Riehle-Colarusso T, Correa A, et al. Observed prevalence of congenital heart defects from a surveillance study in China. *J Ultrasound Med*. 2011;30(7):989–995.

[27] Schiller O, Greene EA, Moak JP, et al. The poor performance of RSR′ pattern on electrocardiogram lead v1 for detection of secundum atrial septal defects in children. *J Pediatr*. 2013;162(2):308–312.

[28] Exeter DJ, Elley CR, Fulcher ML, et al. Standardised criteria improve accuracy of ECG interpretation in competitive athletes: a randomized controlled trial. *Br J Sports Med*. 2014;48(15):1167–1171.

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