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Variations in Diagnosis and Management of Hemodynamically Significant Patent Ductus Arteriosus Across Neonatal Intensive Care Units in the Children's Hospitals Neonatal Consortium

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Abstract

Objective

Collate patent ductus arteriosus (PDA) guidelines among across Children's Hospitals Neonatal Consortium (CHNC) centers and identify variations in the diagnosis and management of hemodynamically significant PDA (hsPDA).

Study Design:

A descriptive survey requesting written PDA guidelines was sent to CHNC representatives from November 2023-February 2024.

Results

Of 44 centers, 38 (86%) responded; 25 (67%) provided written guidelines. Clinical signs of PDA were included in 18 (72%) guidelines, and 21 (84%) specified echocardiographic criteria for hsPDA. Ibuprofen was the most common first-line therapy, followed by acetaminophen and indomethacin. Most centers outlined a stepwise management approach including fluid restriction, diuretics, pharmacotherapy, and transcatheter closure. Surgical ligation was less frequently recommended.

Conclusions

A majority of CHNC centers maintain written hsPDA guidelines incorporating clinical and echocardiographic criteria. Management emphasizes a step-wise approach from expectant to active management with pharmacotherapy and increasing adoption of transcatheter closure, highlighting evolving practice patterns in neonatal PDA care.

INTRODUCTION

Patent ductus arteriosus (PDA) remains a common and clinically significant cardiovascular conditions in preterm infants. Hemodynamically significant PDA (hsPDA) is linked to increased risks of bronchopulmonary dysplasia, necrotizing enterocolitis, intraventricular hemorrhage, and prolonged neonatal intensive care[ref. 1, 2, 3, 4]. Diagnosis of hsPDA is challenging, as clinical signs are nonspecific, necessitating objective echocardiographic assessment. Over the decades, management strategies have shifted from surgical ligation toward an conservative approach with fluid restriction, diuresis and ventilator optimization or selective pharmacotherapy with ibuprofen, indomethacin, or acetaminophen. Advances in transcatheter closure techniques offer minimally invasive alternatives for infants. Despite these evolving approaches, variability persists across centers regarding diagnostic thresholds, timing of

intervention, and preferred therapeutic modalities, reflecting ongoing uncertainty and the absence of standardized, evidence-based guidelines in neonatal PDA care.[ref. 5]

The objective of this study was to collate PDA management protocols from centers in the Children's Hospitals Neonatal Consortium (CHNC) to characterize current practices in the diagnosis and management of a hsPDA. We highlighted evolving trends in PDA management over the past 15 years using data from the Children's Hospital Neonatal Database (CHND), which reports on outcomes from over 45 participating Level IV neonatal intensive care units (NICUs) across the US and Canada.[ref. 6] To understand the landscape of PDA management, we aimed to determine the prevalence of written PDA management guidelines, the clinical and echocardiographic criteria used to define hsPDA, and the preferred approaches to management strategies. By providing a comprehensive overview of contemporary practice patterns, this work seeks to identify areas of consensus and variability, provide the basis for quality improvement initiatives, and guide the development of standardized, evidence-based strategies for optimal PDA management.

METHODS

Study Design and Data Source

We performed a descriptive observational study reviewing PDA management guidelines among North American neonatal intensive care units (NICUs) participating in the CHNC (44 centers at the time of the study). CHNC centers are level IV NICUs that serve as regional referral centers providing advanced care. Participating centers have > 400 annual admissions or > 25 NICU beds and care for a majority of outborn infants (> 50%). The study was approved by the University of Tennessee Health Science Center Institutional Review Board (22-08975-NHSR).

Survey Distribution and Data Collection

Between November 2023 and February 2024, we emailed designated representatives at each CHNC center to determine the presence of a written PDA management guideline for premature infants and to request a copy if available. Follow-up communication was performed as needed. Ten domains were predefined for data extraction: patient population; prophylaxis (24–48 h); early medical therapy (first week); rescue therapy (after the first week); medication dosing; conservative management; definitive closure (transcatheter or surgical); clinical criteria for hsPDA; echocardiographic parameters; and management of post-ligation syndrome. Two authors (MK and SG) reviewed all guidelines, with additional authors reviewing subsets. Discrepancies were resolved by consensus.

Statistical Analysis

Analyses were descriptive. Data are presented as counts and percentages of guidelines addressing each domain and specific elements, using the total number of guidelines as the denominator. No analyses

were performed to assess associations with clinical outcomes. Analyses were conducted using SAS Enterprise Guide version 8.3 (SAS Institute Inc., Cary, NC, USA).

RESULTS

The response rate was 86% (n = 38/44). Of the 38 responding centers, 66% (n = 25/38) shared a written PDA guideline, 34% (n = 13/38) reported having none (Fig. 1). Among the 25 guidelines reviewed, 72% of centers (n = 18/25) defined a target population (Fig. 2**).** Of these, 83% (n = 15/18) applied to infants < 33 weeks' gestation, 61% (n = 11/18) to infants < 30 weeks, 39% (n = 7/18) to infants < 28 weeks, and 11% (n = 2/18) to infants < 27 weeks.

Timing for Screening for hsPDA

Risk- and/or symptom-based PDA screening was described in 92% (n = 23/25) of centers. Gestational age alone was used in 12% (n = 3/25), while clinical signs alone were used in 24% (n = 6/25). A combination of gestational age and clinical signs was used in 32% (n = 8/25) of centers. The timing of initial screening was specified in 60% (n = 15/25) of centers: 8% (n = 2/25) screened within 36 hours for infants < 27 weeks and later in the first week for those ≥ 27 weeks. Symptom-based screening occurred later in the first week in 40% (n = 10/25) of centers, and 12% (n = 3/25) delayed screening until the second week of life.

Clinical and Echocardiographic Criteria

Clinical criteria for hsPDA were described in 80% (n = 20/25) of centers (Fig. 3), of which 95% (n = 19/20) referenced respiratory support requirements. Among these, 11% (n = 2/19) required intubation, 37% (n = 7/19) specified at least noninvasive ventilation or nasal continuous positive airway pressure, 42% (n = 8/19) cited escalating support, and 5% (n = 1/19) used a respiratory severity score > 1.8. Other clinical indicators included pulmonary edema (n = 8/20, 40%), cardiomegaly (n = 6, 30%), pulmonary hemorrhage (n = 5, 25%), widened pulse pressure (n = 4, 20%), hyperdynamic precordium (n = 3, 15%), bounding pulses (n = 2, 10%), frequent apnea/bradycardia/desaturation events (n = 2, 10%), palmar pulses (n = 1, 5%), intraventricular hemorrhage (n = 1, 5%), and spontaneous intestinal perforation (n = 1, 5%). A formal clinical scoring system was reported in 12% (n = 3/25) of centers. Echocardiographic criteria were described in 88% (n = 22/25) of centers, commonly including ductal diameter, isovolumic relaxation time, left atrium-to-aorta ratio, and flow reversal in the descending aorta. Less frequently used parameters included flow reversal in the celiac trunk or middle cerebral artery (Table 1**).**

Expectant Management

Expectant management was addressed by 36% (n = 9/25) of centers. All recommended fluid restriction (120–140 mL/kg/day), 78% (n = 7/9) recommended increased PEEP (without a specified target), 56% (n

= 5/9) included diuretics, and 33% (n = 3/9) targeted hemoglobin > 12 g/dL. One center limited fluid restriction to the first postnatal week. None recommended withholding feeds; 22% (n = 2/9) limited feeds to trophic volumes, and 12% (n = 3/25) explicitly encouraged feeding during conservative management.

Prophylactic Therapy for High-Risk Infants

Prophylactic pharmacotherapy was recommended for high-risk infants at 24% (n = 6/25) of centers. These were defined as risk for intraventricular hemorrhage in 33% (n = 2/6) of centers or infants with gestational age < 25–26 weeks without antenatal steroids in 33% (n = 2/6) of centers. Four centers used indomethacin for prophylaxis. The remaining two centers identified high-risk infants for prophylaxis as those ≤ 26 weeks with a moderate to large volume shunt on echocardiogram; each of these centers used IV acetaminophen for prophylaxis at a dose of 15 mg/kg every 6 hours for 12 doses.

Active Management with Pharmacotherapy

Early pharmacotherapy (within first week of life) was offered in 52% (n = 13/25) of centers. Rescue pharmacotherapy was offered in 84% (n = 21/25) (Fig. 4**).** Among these, 38% (n = 8/21) initiated rescue therapy before 2 weeks of age, 19% (n = 4/21) after 2 weeks, and 5% (n = 1/21) up to 6 weeks; 38% (n = 8/21) did not specify timing. A single course only was recommended in 4% (n = 1/25) of centers, two courses were recommended in 32% (n = 8/25) of centers, and 8% (n = 2/25) of centers recommended up to four courses of medical therapy. Medication dosing and routes are detailed in Table 2. Feeding guidance during pharmacotherapy was provided in 64% (n = 16/25): none recommended holding feeds; 16% (n = 4/25) recommended trophic feeds, 16% (n = 4/25) restricted volume, 16% (n = 4/25) allowed unrestricted feeding, and 16% (n = 4/25) recommended feeding without specifying volume.

Active Management with Definitive Closure

Guidance on transcatheter closure was included in 92% (n = 23/25) of centers, with 83% (n = 19/23) recommending pharmacotherapy prior to device closure. Additionally, 22% (n = 5/23) recommended waiting until 14 days of life and 13% (n = 3/23) until 21 days. A minimum weight for device closure was specified in 57% (n = 13/23), ranging from 650 to 1800 grams. Surgical ligation guidance was provided in 48% (n = 12/25) of centers; 30% (n = 4/12) reserved it for infants small for transcatheter closure. Minimum age thresholds for ligation were 14 days (16%), 21 days (8%), and 28 days (8%).

Post-Ligation Syndrome

Only one center (4%) provided guidance on post-ligation syndrome, recommending avoidance of vasopressors that increase afterload and monitoring for early hypotension as a potential complication.

DISCUSSION

Clinical practice surrounding patent ductus arteriosus (PDA) management has evolved over the past decade, reflecting advances in neonatal care, echocardiographic assessment, and procedural

capabilities[ref. 4, 6]. Our synthesis of PDA guidelines across CHNC centers demonstrates that most institutions employ structured, protocol-driven approaches integrating both clinical and echocardiographic criteria to define a hsPDA. Stepwise management with expectant measures, progressing to pharmacologic therapy, and escalating to transcatheter or surgical closure when indicated. Despite this shared framework, considerable variability persists in screening strategies, diagnostic thresholds, and treatment pathways. These findings suggest that contemporary PDA care in tertiary NICUs is guided by common principles but remains highly center and neonatologist specific, reflecting ongoing uncertainty regarding optimal patient selection, timing of intervention, and long-term outcomes[ref. 4].

Our findings align with prior registry-based and observational studies demonstrating a shift away from routine PDA closure toward conservative, individualized management strategies[ref. 4, 7, 8]. This transition reflects evidence suggesting that early routine intervention does not consistently improve outcomes and may expose infants to unnecessary risk[ref. 7, 8, 9]. Notably, 33% of CHNC centers explicitly incorporate expectant strategies such as fluid restriction and diuretic use, reinforcing the growing acceptance of non-interventional approaches. By collating institutional guidelines rather than relying on retrospective clinical data, this study provides novel insight into how evidence is operationalized at the bedside. Understanding how centers translate evidence into protocols is essential for interpreting practice variation and identifying opportunities to standardize care.

Additionally, observation that only 66% of CHNC centers maintain formal PDA guidelines underscores the lack of consensus that continues to define this field. Even among centers with established protocols, there is marked heterogeneity in nearly all aspects of care, including screening, diagnostic criteria, pharmacologic regimens, and thresholds for procedural intervention. Given that CHNC centers are high-acuity referral NICUs, this variability is particularly notable and likely reflects differences in institutional culture, available expertise, and interpretation of a complex and evolving literature base. The absence of uniform standards highlights the challenges clinicians face in balancing risks and benefits in a population with highly variable clinical trajectories.

Variability in screening practices further illustrates the uncertainty in PDA management[ref. 9, 10, 11]. Most centers report using risk[ref. 9, 10, 12] or symptom-based screening approaches, consistent with evidence suggesting that treatment decisions should not be based solely on ductal patency[ref. 13]. However, the timing of initial echocardiographic evaluation varies widely, ranging from early targeted risk-based-screening within the first 36 hours of life to later symptoms-based assessment within the first two weeks. This heterogeneity mirrors findings from randomized trials[ref. 7, 14, 15] and meta-analyses[ref. 8, 9] showing no clear benefit of routine early treatment compared with expectant management. Increasing emphasis on identifying hsPDA based on physiologic significance rather than anatomic presence alone is reflected in the widespread use of combined clinical and echocardiographic criteria.[ref. 13, 16, 17] Nonetheless, the lack of standardized definitions and limited adoption of validated scoring systems highlight an important gap in the field.

Conservative or expectant management to, either before or in place of pharmacotherapy, was reported by nine centers. This may reflect a feeling among neonatologists that conservative management does not warrant explicit recommendations, or it does not differ from routine neonatal care, or it may be that very few CHNC center feel that conservative management is optimal for patients with hsPDA. There may be a coming shift in practice as recent randomized trials, including BeNeDuctus, BabyOSCAR, and The PDA Randomized Clinical Trial, each concluded that conservative management was as good or better than pharmacologic treatment. However, interpretation of these results is limited by early termination, treatment crossover, and exclusion of the most critically ill infants.[ref. 7, 18, 19] However, the increase in PDA pharmacotherapy and unchanged rates of definitive PDA closure at CHNC centers suggests that shift had not yet happened as of 2022.[ref. 6]

Several guidelines addressed feeding during conservative management or during treatment. During conservative management, two centers recommended limiting feeding to trophic volumes. More centers offered feeding recommendations during treatment, and guidelines were split between limiting feeding volume and offering full feeds. Despite limited data to guide feeding practices during PDA therapy, reducing or holding feeds has been shown to be associated with longer time to reach full feeds while not reducing gastrointestinal outcomes during PDA treatment.[ref. 20, 21, 22] Furthermore, holding feeds during therapy has been suggested as the possible underlying cause of poor outcomes reported to be associated with pharmacotherapy in recent randomized trials.[ref. 7, 23] None of the guidelines reviewed included recommendations to hold feeds during pharmacotherapy.

Consistent with prior literature, most centers define hsPDA using a combination of clinical indicators, particularly respiratory support, and echocardiographic markers such as flow reversal in the descending aorta. However, specific criteria remain inconsistent and often subjective. A minority of centers employ formal clinical or echocardiographic scoring systems, despite emerging evidence that composite measures may better correlate with meaningful outcomes.[ref. 9] Pharmacologic management reflects both convergence and divergence. Ibuprofen remains the most common first-line agent in CHNC guidelines, whereas acetaminophen, despite increasing use in clinical practice[ref. 6], is less frequently incorporated into formal protocols. This discrepancy between guidelines and real-world practice highlights the dynamic nature of PDA management and suggests that institutional protocols may lag evolving clinician preferences and emerging evidence.

The clinical implications of these findings are significant. The shared stepwise framework observed across centers supports a pragmatic approach to PDA management that prioritizes individualized care while minimizing unnecessary intervention. Incorporating both clinical and echocardiographic data into decision-making may improve consistency in identifying infants most likely to benefit from treatment.[ref. 4] At the same time, the variability in definitions and thresholds underscores the need for multidisciplinary collaboration, particularly between neonatology and cardiology, to ensure physiologically meaningful assessment. The increasing adoption of transcatheter closure further emphasizes the importance of institutional readiness, including access to specialized expertise and

standardized referral pathways.[ref. 24] Overall, these findings highlight opportunities for quality improvement initiatives aimed at harmonizing care while preserving flexibility for patient-specific decision-making.

Several limitations should be considered when interpreting these results. First, reliance on written guidelines may not accurately reflect bedside practice, where clinician judgment and patient-specific factors often influence decision-making. Second, this descriptive study does not include patient-level data or outcomes, limiting the ability to assess the clinical impact of different management strategies. Third, the sample is restricted to CHNC centers, which are large, tertiary NICUs; therefore, findings may not be generalizable to smaller or non-referral centers. Additionally, guideline collection preceded several recent high-impact studies and consensus statements, which may further influence current practice. As such, the observed variability likely reflects an evolving evidence base and ongoing shifts in clinical paradigms.

In conclusion, PDA management across CHNC centers is characterized by a structured, stepwise approach that integrates clinical and echocardiographic assessment, selective pharmacotherapy, and increasing use of transcatheter closure. While variability remains in screening, diagnosis, and treatment thresholds, most centers share a common conceptual framework emphasizing targeted, physiology-based care. Ibuprofen continues to be the most recommended first-line agent, and transcatheter closure is increasingly favored over surgical ligation. These findings underscore a broader shift toward individualized, evidence-informed management while highlighting persistent gaps in knowledge. Future prospective studies are needed to better define optimal screening strategies, refine criteria for hemodynamic significance, and compare long-term outcomes of expectant versus active management approaches.

Abbreviations

CHD congenital heart disease

CHNC Children’s Hospitals Neonatal Consortium

CICU cardiac intensive care unit

NICU neonatal intensive care unit

PDA Patent ductus arteriosus

Declarations

Sources of Financial Assistance

None

Potential Conflicts of Interest

PTL and MFW received speaker honorariums from Abbott Congenital Heart. Other authors declare no conflicts of interest.

Author Contributions:

SHG and MW, developed the project. SHG, PTL, SM, SK, SS, AR, RR, MKB drafted the manuscript, which was then critically reviewed, revised, and approved by all authors. The authors take full responsibility for the manuscript.

Data Availability Statement

The data that support the findings of this study are available from the authors upon reasonable request.

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Tables

Table 1
Echocardiographic Markers of Hemodynamically Significant Patent Ductus Arteriosus (hsPDA)

Left to right shunt	**Number of Centers**	**Frequency, n = 25**
	7	**28%**
Diastolic flow pattern in descending aorta or mesenteric artery	16	64%
Significant patent ductus arteriosus flow velocity		
<1.5 m/s	3	12%
<2 m/s	3	12%
<2.5 m/s	1	4%
<3 m/s	1	4%
Significant LA:Ao ratio		
>1.3	3	12%
>1.4	2	8%
>1.5	7	28%
>2	4	16%
Significant PDA diameter		
≥1 mm	1	4%
≥1.5 mm	8	32%
≥2 mm	2	8%
Assess PDA diameter by body weight	3	12%
Other specified echo markers	20	80%
Echocardiogram scoring system	7	28%

Echocardiographic criteria were described in 88% (n = 22/25) of centers. The other markers include LPA velocity, LA dilation, LV dilation, Unrestricted PDA flow, PDA:PA ratio, LVO:RVO ratio, IVRT, PV D velocity, Mitral E velocity, Mitral valve dilation, Mitral regurgitation

Table 2
Medication Dosing Specifications,

Medication	Dose	Centers	Frequency (n = 25)
Indomethacin IV (10 centers)			
	0.1 mg/kg x 3 doses	1	4%
	0.2 mg/kg x4-6 doses	1	4%
	Variable dosing by postnatal age	8	32%
	IV dosing	10	40%
Ibuprofen (13 centers)			
	High dose (15–20 mg/kg)	7	28%
	Standard dose (10 mg/kg)	6	24%
	IV dosing preferred	2	8%
	Enteral dosing preferred	9	36%
	Route not specified	2	8%
Acetaminophen (17 centers)			
	15 mg/kg q6 hours x 3 days	7	28%
	15 mg/kg q6 hours x 5 days	1	4%
	IV dosing preferred	5	20%
	Enteral dosing preferred	7	28%
	Route not specified	5	20%
Medication dosing not specified		4	16%

Compiled medication and dosing regimens abstracted from 21 centers' PDA management guidelines, where such information was included. IV=intravenous.

Figures

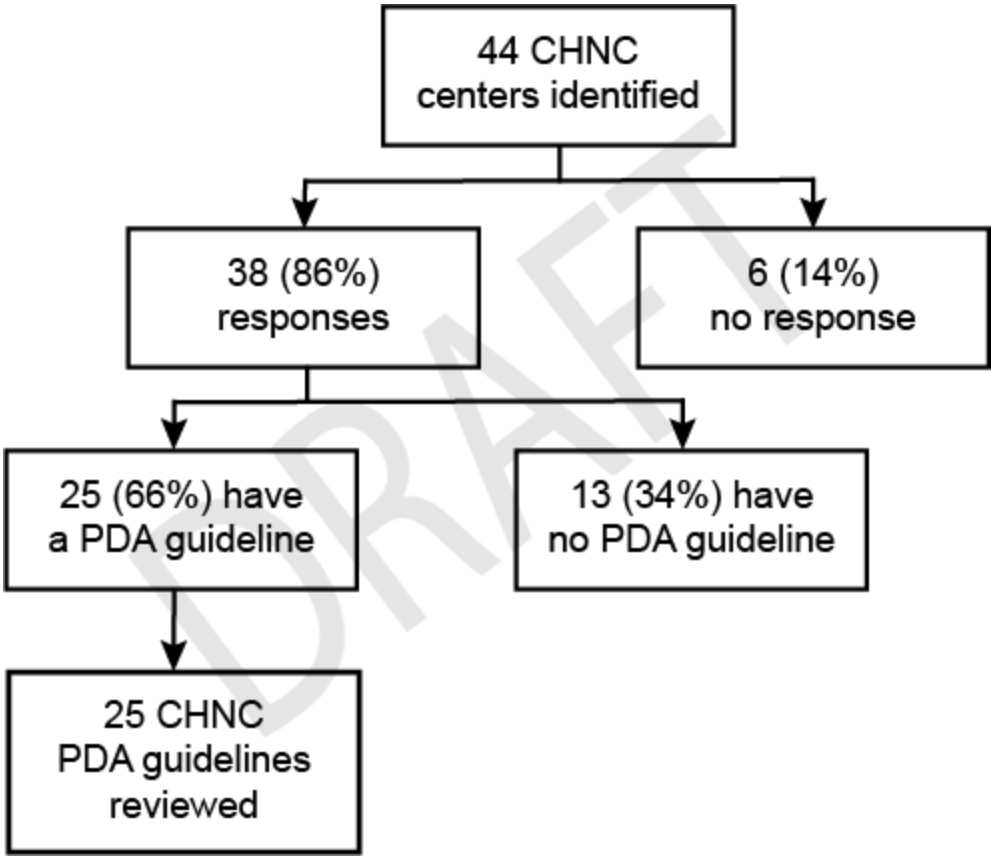


Figure 1

Study Diagram

DRAFT

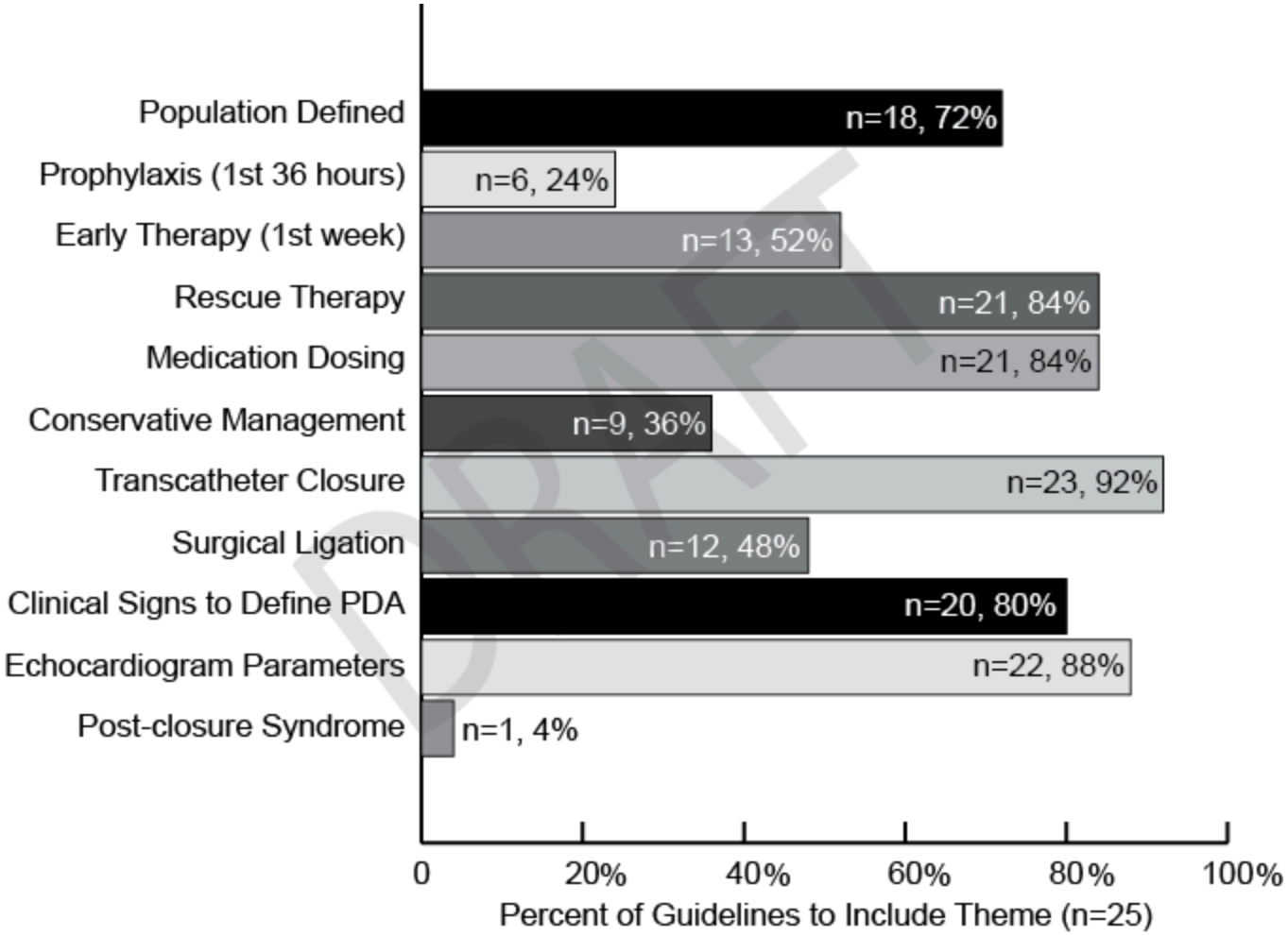


Figure 2

Assessment and Management Themes Discussed in Patent Ductus Arteriosus Guidelines.

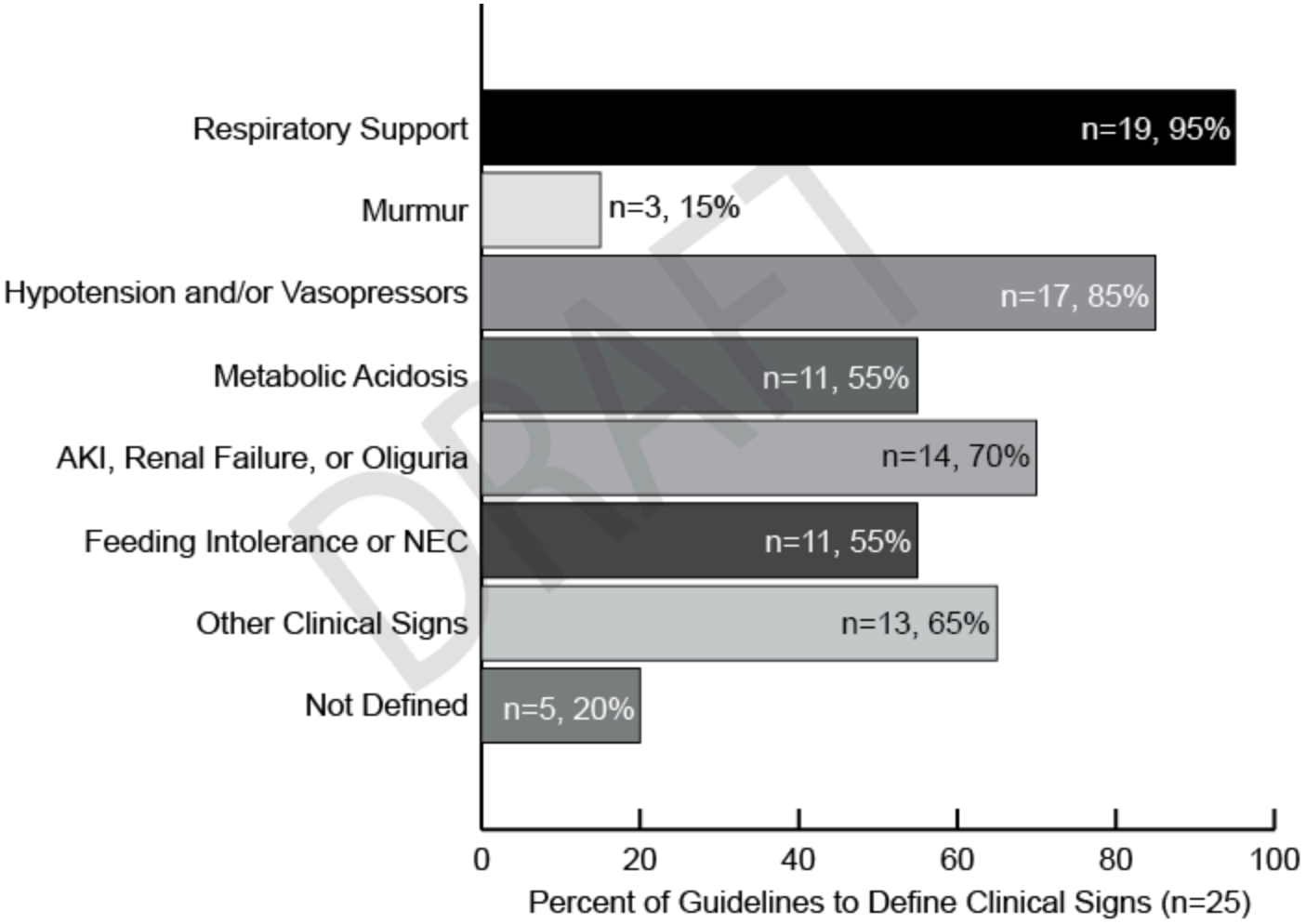


Figure 3

First-line Choice of Pharmacotherapy: (A) Early medical therapy within the first postnatal week; and (B) rescue therapy after the first week of age, as recommended by 13 and 21 center guidelines, respectively.

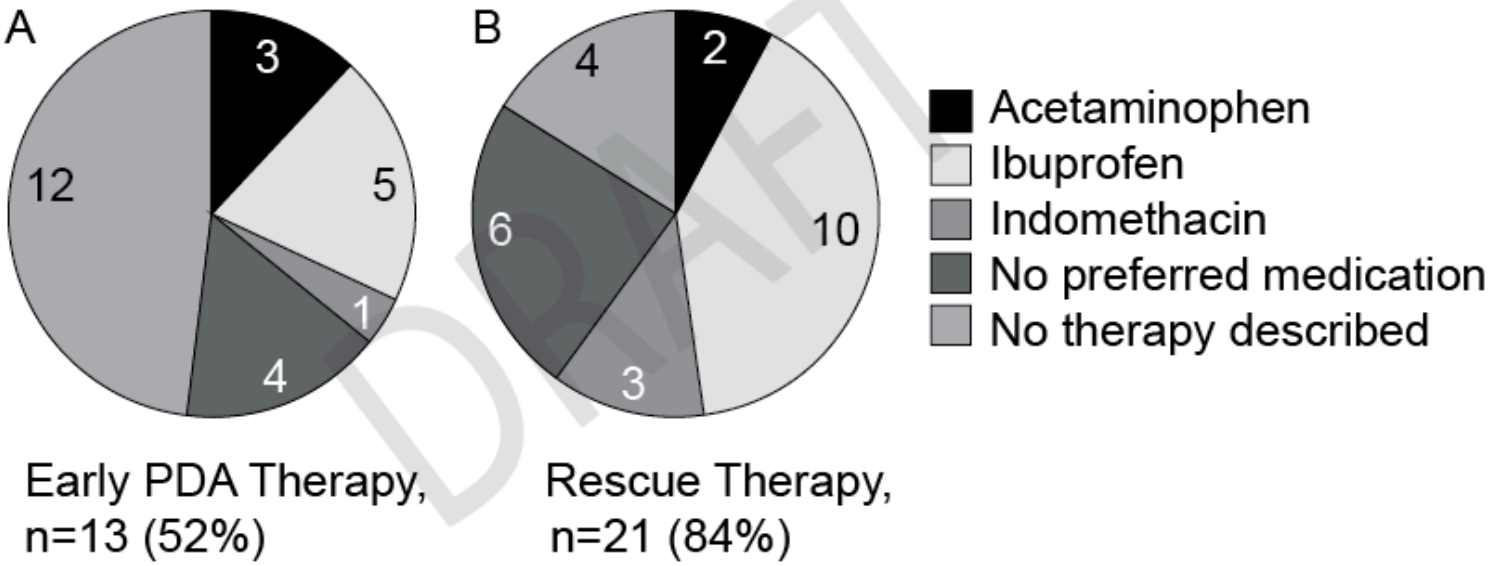


Figure 4

Clinical Signs to Define a Hemodynamically Significant PDA