Pilot Study Comparing Modified Finnegan Scoring Versus Adjusted Scoring System for Infants With Iatrogenic Opioid Abstinence Syndrome After Cardiothoracic Surgery

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OBJECTIVES To compare the modified Finnegan Scoring System (modified Finnegan) with an Adjusted Scoring System Criteria (adjusted Finnegan) for infants after cardiothoracic surgery with iatrogenic opioid abstinence syndrome (IOAS).

METHODS This was a retrospective, observational pilot study. This study was conducted in a tertiary care academic hospital. Infants after cardiothoracic surgery with IOAS transferred between the pediatric intensive care unit and neonatal intensive care unit between January 1, 2014, and January 31, 2016, were included retrospectively. The main outcome variable was to compare the area under the curve for the mean modified Finnegan versus adjusted Finnegan.

RESULTS Twenty-five patients were included in the study. Twenty patients with at least 30 scores were included in the final analysis. Overall, the modified Finnegan scores were at least 2 points higher than the adjusted Finnegan. The difference in area under the curve was 34.6 ($p < 0.001$).

CONCLUSIONS Use of the modified Finnegan tool for older infants with IOAS could overestimate withdrawal, leading to unnecessary interventions.

ABBREVIATIONS AUC, area under the curve; CHD, congenital heart disease; CI, continuous infusion; CTS, cardiothoracic surgery; GI, gastrointestinal; IOAS, iatrogenic opioid abstinence syndrome; LOS, length of stay; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit; WAT-1, Withdrawal Assessment Tool-1

KEYWORDS Finnegan scoring; infant; neonate; opioid; sedation; withdrawal

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Introduction

Infants in the neonatal intensive care unit (NICU) or pediatric intensive care unit (PICU) are given an opioid continuous infusion (CI) as part of their analgesic and sedative regimen. If these opioid CIs are abruptly discontinued or tapered too quickly, infants may develop iatrogenic opioid abstinence syndrome (IOAS). Symptoms of IOAS can be categorized into 3 different subgroups: central nervous system irritability (e.g., agitation, grimacing), gastrointestinal (GI) dysfunction (e.g., vomiting, diarrhea), and autonomic dysfunction (e.g., tachycardia, hypertension). If infants do not receive appropriate interventions, IOAS may lead to increased morbidity, including patient discomfort and prolonged hospital length of stay (LOS).¹ The American Academy of Pediatrics guideline on neonatal drug withdrawal recommends enteral morphine and methadone as first-line pharmacologic treatment options and enteral clonidine as an adjunct agent.²

A validated monitoring tool is needed to identify symptoms to guide treatment. A number of tools are available, including the modified Finnegan Scoring System (modified Finnegan) and the Withdrawal Assessment Tool-1 (WAT-1).^{2–4} The most commonly used scoring tool in US NICUs is the modified Finnegan.⁵ This tool was developed to assess opioid withdrawal in newborns exposed *in utero* to opioids and is composed of 21 different criteria regarding central nervous system, metabolic, vasomotor, respiratory, and GI disturbances.⁶ Newborns with a score ≥ 8 are considered to have withdrawal and may require pharmacologic intervention. When this tool is applied to infants >14 days of life with IOAS, some discrepancies have been noted at our institution. Specifically, clinicians within our institution using the modified Finnegan to guide tapering opioids in infants after cardiothoracic surgery (CTS) have noted an overestimation of the likelihood of IOAS due to some of the newborn-specific criteria (e.g., duration of sleeping after feeds) within this tool. As a

result, these scoring discrepancies may be associated with prolonged opioid exposure and perhaps increased LOS. Therefore, the aim of this study was to determine if exclusion of newborn-specific criteria from the modified Finnegan could affect the score and, indirectly, the management of opioid withdrawal in infants with IOAS after CTS.

Materials and Methods

This was an Institutional Review Board–approved, retrospective, observational pilot study conducted in a tertiary care academic hospital. For the purpose of this study an infant was defined as a baby with a postmenstrual age ≥ 37 weeks and a postnatal age ≥ 14 days of life at time of transfer from the PICU to NICU. At the Children's Hospital at OU Medical Center, infants with congenital heart disease (CHD) are initially admitted to the NICU but are transferred to the PICU after CTS. Once stabilized, these infants are transferred back to the NICU. After CTS, infants transferred between the PICU and NICU between January 1, 2014, and January 31, 2016, were included if they received >5 days of opioid CI and/or >1.5 mg/kg cumulative fentanyl exposure (or fentanyl equivalent).⁷ Infants were excluded if they were not scored using the modified Finnegan, had GI and/or neurologic congenital defects that could potentially affect scoring with the modified Finnegan, had grade 3 or 4 intraventricular hemorrhage, or had surgical intervention for necrotizing enterocolitis. Patients were identified by International Classification of Diseases codes for CHD through the institution's electronic databases, Meditech (Medical Information Technology Inc, Westwood, MA) and Crib Notes (Grand Rounds Software LLC, Bryn Mawr, PA).

Data collection included demographics, postnatal age at the time of transfer from PICU to NICU, weight, NICU LOS prior to surgery and after surgery, and PICU LOS. WAT-1 scoring is routinely performed in the institution's PICU, and these scores were collected for the 24-hour period prior to transferring out of the PICU. The modified Finnegan score is routinely performed in the institution's NICU and was collected for a 7-day period following the transfer from the PICU to the NICU. At the study institution, 2 consecutive modified Finnegan scores ≥ 8 are considered opioid withdrawal and may require pharmacologic treatment. In addition to the modified Finnegan, a separate score was calculated retrospectively by the study investigators, defined as the "Adjusted Scoring System Criteria" (adjusted Finnegan; Table 1). This tool excluded newborn-specific factors that were identified by the neonatal research team, including a clinical nurse specialist, neonatologist, and neonatal clinical pharmacist. The goal was to determine the most appropriate factors *a priori* to remove from the modified Finnegan for use in older infants with IOAS (Figure 1) as symptoms that occur primarily in the newborn period (e.g., sleeping after feeds, hyperactive

Moro reflex, nasal stuffiness/flaring) or symptoms that may be altered in infants with heart failure (e.g., poor oral feeding and tachypnea).

Sedative and analgesic CI exposure and the agents used to prevent and/or treat IOAS were collected (e.g., methadone, diazepam, clonidine). For methadone, the starting and final doses and dose/interval increases were collected during the 7-day period the modified Finnegan scores were recorded. Interventions for IOAS were documented (e.g., taper increased, as needed [PRN] dose given).

The primary objective was to compare the mean difference between the modified Finnegan and the adjusted Finnegan plotted at each time point during the 7-day period. Secondary objectives included identification of interventions required for patients with a modified Finnegan score ≥ 8 and comparison of the modified Finnegan, adjusted Finnegan, and WAT-1 scores during the 7-day period. At our institution, WAT-1 scores are not performed in the NICU, so these values were retrospectively calculated based on the modified Finnegan; however, the study investigators were not able to conduct the poststimulus portion of the WAT-1. Therefore, 2 theoretical WAT-1 scores were calculated for each modified Finnegan: WAT-1 High (assigned poststimulus portion as a "2") and WAT-1 Low (assigned poststimulus portion as a "0"). At the study institution, 2 consecutive WAT-1 scores ≥ 4 are considered opioid withdrawal and may require pharmacologic intervention.

Descriptive statistics were employed for study analysis. To account for variability in the number of modified Finnegan scores collected per patient, only the first 30 observed time points after transfer back to the NICU were analyzed. To compare the mean modified Finnegan with the adjusted Finnegan at each time point, area under the curve (AUC) was computed using the trapezoidal method. With this approach, each patient was used as his or her own control and the difference in AUC (modified Finnegan AUC – adjusted Finnegan AUC) was computed for each patient. These differences were assessed for normality using the Shapiro-Wilk test and then compared with "no change" using the Student paired *t*-test.

Results

Patient Demographics. Eighty-seven patients were identified for potential inclusion in the study. Sixty-two patients were excluded from analysis. The most common reason for exclusion was that the modified Finnegan scores were not documented ($n = 53$). Additionally, 3 patients were excluded secondary to postnatal age at time of transfer of <14 days ($n = 3$), neurologic and/or GI congenital defects ($n = 3$), or opioid CI duration <5 days ($n = 3$). Twenty-five patients met inclusion criteria (Table 2). The median postmenstrual age was 42 weeks, with a median postnatal age of 0.8 months at the time of the transfer from the PICU to the NICU.

Table 1. Comparison of Scoring System Criteria

	Modified Finnegan Scoring Criteria	Adjusted Scoring Criteria (Non-neonatal)
High-pitched cry <5 min (score = 2) ≥5 min (score = 3)	Included	Included
Sleeping after feeding <3 hr (score = 1) <2 hr (score = 2) <1 h (score = 3)	Included	Excluded
Hyperactive reflexes Moro reflex (score = 2) “Markedly” Moro reflex (score = 3)	Included	Excluded
Tremors disturbed Mild (score = 1) Moderate-severe (score = 2)	Included	Included
Tremors undisturbed Mild (score = 3) Moderate-severe (score = 4)	Included	Included
Increased muscle tone (score = 2)	Included	Included
Excoriation (score = 1) Myoclonic jerks (score = 3)	Included	Included
Sweating (score = 1)	Included	Included
Temperature 38°C–38.3°C (score = 1) >38.3°C (score = 2)	Included	Included
Frequent yawning (score = 1)	Included	Included
Mottling (score = 1)	Included	Included
Respiratory rate >60 breaths/min (score = 1) >60 breaths/min with retractions (score = 2)	Included	Excluded
Nasal Stiffness (score = 1) Flaring (score = 2)	Included	Excluded
Sneezing (score = 1)	Included	Included
Excessive sucking (score = 1)	Included	Included
Poor feeding (score = 2)	Included	Excluded
Regurgitation (score = 2) Projectile vomiting (score = 3)	Included	Included
Stools Loose (score = 2) Watery (score = 3)	Included	Included

Their median PICU LOS after CTS was 11 days. The median NICU LOS after transfer from PICU was 24 days.

The median duration of opioid CIs was 13 days (range, 6–60 days). Most patients received a concomitant sedative CI. Most patients received midazolam CI ($n = 16$; 64%) and/or dexmedetomidine CI ($n = 15$; 60%). An additional 3 patients (12.0%) received a ketamine CI.

IOAS Assessment and Treatment. Twenty-two patients had WAT-1 scores documented for the 24-hour period prior to transfer from the PICU to NICU. The

median WAT-1 score was 1 (range, 0–3). All patients had modified Finnegan scores documented upon transfer to the NICU. However, 5 were excluded for further analysis of the primary objective because they had fewer than 30 modified Finnegan scores available. The mean modified Finnegan compared with the mean adjusted Finnegan scores at each time point was consistently higher (Figure 1). The difference in AUC between scores was 34.6 ($p < 0.001$). Table 3 provides an example for the modified Finnegan and

Figure 1. Mean modified Finnegan scores compared with mean adjusted scores. The y-axis indicates the mean score; x-axis, score number; red line, modified Finnegan; blue line, adjusted Finnegan.

adjusted Finnegan for 1 patient for 5 scores. Of the 5 scores highlighted, the modified Finnegan score was at least 2 points higher than the adjusted Finnegan at each time point. Of note, 2 of the 5 modified Finnegan scores were ≥ 8 ; however, these scores were not consecutive and thus did not meet the study criteria for withdrawal.

Figure 2 shows the maximum modified Finnegan for each patient and the accompanying calculated adjusted Finnegan, WAT-1 High, and WAT-1 Low scores at that specific time point. There was considerable interpatient variability in scores and inpatient variability when different tools were applied per time point. Nine patients (45.0%) had a modified Finnegan score ≥ 8 . Only 1 patient (5.0%) had a modified Finnegan score ≥ 8 and WAT-1 High and WAT-1 Low scores ≥ 4 , indicating withdrawal based on the definitions for this study. Seven patients (35.0%) had a modified Finnegan and WAT-1 High score indicating withdrawal. Five patients (25.0%) only had a WAT-1 High score indicating withdrawal, and their modified Finnegan scores were < 8 .

One patient (5.0%) only had an elevated modified Finnegan score. The remaining 6 patients (30.0%) had no elevated scores.

Of 25 patients included in the study, 23 (92.0%) received an enteral agent for prevention/treatment of withdrawal. All 23 received enteral methadone. The median starting and final methadone doses in mg/kg/day during the 7-day period were 0.3 and 0.14, respectively. Four patients (17.4%) required an increase in their methadone dose during the 7-day period. Most patients (91.3%) had at least 1 decrease in dose and/or change in frequency with their methadone during this time period. In addition to methadone, 7 patients (28%) received diazepam, and 3 (12%) patients received clonidine.

Overall, 4 of the 9 patients (44.4%) who had an elevated modified Finnegan score > 8 received a pharmacologic intervention. Table 4 provides a summary of their corresponding calculated score and intervention. Most of these (75%) required an adjustment in their methadone dose.

Table 2. Patient Demographics (N = 25)

Variable	n (%) or Median (Range)
Sex, male	16 (64)
Postmenstrual age at time of transfer to NICU, wk	42 (37–53)
Postnatal age at time of transfer to NICU, mo	0.8 (0.5–4.4)
Weight, kg	3.3 (1.84–4.79)
PICU LOS, days	11 (4–31)
NICU LOS after transfer from PICU, days	24 (7–181)

LOS, length of stay; NICU, neonatal intensive care unit; PICU, pediatric intensive care unit

Table 3. Withdrawal Scoring For Patient 14 for Scores 26–30

Signs and Symptoms (Assigned Scores)	Score 26		Score 27		Score 28		Score 29		Score 30	
	mF	aF	mF	aF	mF	aF	mF	aF	mF	aF
High pitched crying										
<5 min (2)										
≥5 min (3)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Feeding after sleeping										
<3 hr (1)										
<2 hr (2)	2	NA			2	NA	2	NA	2	NA
<1 hr (3)			3	NA						
Absent (0)										
Tremors										
Mild tremors when disturbed (1)	1	1	1	1	1	1	1	1	1	1
Marked tremors when disturbed (2)										
Mild tremors when undisturbed (3)										
Marked tremors when undisturbed (4)										
Absent (0)										
Muscle tone										
Increased tone (2)									2	2
Absent (0)	0	0	0	0	0	0	0	0		
Skin excoriation										
Present (1)			1	1	1	1	1	1	1	1
Absent (0)	0	0								
Seizures										
Myoclonic jerks (3)										
Generalized convulsions (5)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Sweating										
Present (1)			1	1			1	1		
Absent (0)	0	0			0	0			0	0
Fever										
37.5°C–38.0°C (1)										
>38.0°C (2)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Yawning										
Present >3–4 times/interval (1)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Mottling										
Present (1)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Nasal stuffiness										
Present (1)	1	NA	1	NA						
Absent (0)					0	NA	0	NA	0	NA
Sneezing										
Present (1)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Sucking										
Excessive sucking (1)	1	1	1	1	1	1	1	1		
Absent (0)									0	0
Feeding										
Poor feeding (2)	2	NA								
Absent (0)			0	NA	0	NA	0	NA	0	NA
Regurgitation/projectile vomiting										
Regurgitation (2)										
Projectile vomiting (3)										
Absent (0)	0	0	0	0	0	0	0	0	0	0
Stool consistency										
Loose (2)			2	2			2	2		
Watery (3)										
Absent (0)	0	0			0	0			0	0
Respiratory rate										
Respiratory rate >60 bpm (1)			1	NA						
Respiratory rate >60 bpm with retractions (2)										
Respiratory rate <60 bpm (0)	0	NA			0	NA	0	NA	0	NA
Total score	7	2	11	6	5	3	8	6	6	4

aF, adjusted Finnegan; bpm, breaths per minute; mF, modified Finnegan; NA, variable not included in the adjusted Finnegan

Figure 2. Maximum modified Finnegan score compared with the adjusted and Withdrawal Assessment Tool-1 (WAT-1) scores at the same time point per patient.

Discussion

This pilot study is the first to compare the modified Finnegan tool versus other calculated scores in infants after CTS. This population was selected because these infants are transferred from the PICU to the NICU and are at risk for IOAS. At our institution, it was anecdotally noted that some infants had discrepancies in the need for pharmacologic intervention for withdrawal before and after transfer. These discrepancies may have been due to the symptoms associated with CHD that could have been inflating their modified Finnegan scores (e.g., tachypnea) or the inclusion of newborn factors (e.g., sleep, nasal stuffiness) that may no longer have been relevant at the time of transfer back to the NICU. The modified Finnegan was validated for newborns exposed *in utero* to opioids, so application of this tool in infants with IOAS may not be appropriate.

A recent study by Zimmerman-Baer and colleagues⁸ also raised some concerns regarding application of the modified Finnegan to all infants in the NICU. They performed an observational cohort study assessing the variability of modified Finnegan during the first week of life compared with week 5 or 6 of life in infants not exposed to opioids *in utero*. Modified Finnegan scores were observed for the first 3 days of life (i.e., cohort 1) and for a 3-day period during week 5 or 6 of life (i.e., cohort 2). The median scores in cohort 1 were 2, although there was variability noted in the upper end in the range (i.e., 95th percentile) from day 1 to day 2 of life, 5.5 versus 7. Diurnal variation was noted in the median score during the day and night, 5 versus 2. It is difficult to compare these findings with our own because patients in this study were not exposed to opioids

and there was a limited number of scores documented. However, this study suggests that older infants may have higher scores because they may receive points for some criteria that may be “normal” for their age rather than representative of withdrawal. There may be diurnal variation in scores in older infants.

The adjusted Finnegan was retrospectively calculated for the purpose of this study to limit the effect of newborn factors. We found a significant difference in the AUC between the modified and adjusted Finnegan scores, 34.6 ($p < 0.001$). Overall, the AUC for the adjusted Finnegan was lower than the AUC for the modified Finnegan, thus suggesting that the removal of neonatal criteria in infants resulted in lower scores. During the initial discussions with the investigator team regarding the adjusted Finnegan, it was difficult to determine a threshold for withdrawal after excluding some of the neonatal-specific criteria. Because the WAT-1 was used in our PICU and is validated for infants ≥ 14 days with IOAS, we chose to apply this tool retrospectively for comparison purposes.^{3,4} A total of 7 of the 9 patients with a high modified Finnegan also had WAT-1 High score ≥ 4 , indicating withdrawal. However, only 1 patient had elevated scores for the WAT-1 High and Low and modified Finnegan and also received an intervention. Three other patients received an intervention; however, an intervention may not have been necessary in all cases. One patient had a WAT-1 High of 4, WAT-1 Low of 2, modified Finnegan of 12, and adjusted Finnegan of 8, and received an intervention. Another patient had a WAT-1 High of 4, WAT-1 Low of 2, modified Finnegan of 11, and adjusted Finnegan of 6, and required an intervention. In both of these cases, the WAT-1 Low

Table 4. Interventions Required

Patient Number	Score Number (Day of Score)	Modified Finnegan	Adjusted Finnegan	WAT-1 High	WAT-1 Low	Intervention
6	1 (1)	12	8	4	2	Methadone increased
11	25 (5)	11	8	6	4	Methadone increased
14	27 (6)	11	6	4	2	Methadone increased
16	10 (1)	9	7	4	2	PRN morphine dose given

WAT, Withdrawal Assessment Tool-1

was <3 and there was a noticeable difference in the modified compared with the adjusted Finnegan, suggesting that there were neonatal factors contributing to the elevated modified Finnegan. This could have led to an unnecessary intervention.

It is imperative that the most appropriate tool be used to assess IOAS in neonates and infants. If a tool overestimates the severity of withdrawal symptoms by including newborn-specific factors or factors affected by their disease state, then there is a potential that infants may receive unnecessary interventions and/or a higher cumulative opioid exposure. Several recent studies have found an association between poor neurodevelopmental outcomes and morphine and fentanyl exposure.^{9–11} These studies have suggested that increased opioid exposure may lead to an increased incidence of cerebellar injury and lower cerebellar diameter at equivalent age, along with a reduction in intelligence quotient scores at age 5 years. To our knowledge, there are no current studies that have evaluated the effect of enteral administration of opioids on neurodevelopment. However, these findings suggest significant concerns with unnecessary, routine use of opioids.

There are several limitations. First, the data were collected retrospectively from a single center. Inclusion of data from other NICUs with different standards of care may have yielded different outcomes. Second, we only included infants with CHD that required surgical repair. It is possible if we had evaluated another NICU subpopulation with IOAS (e.g., infants with chronic lung disease) that we would have found different results comparing the adjusted Finnegan versus the modified Finnegan. However, we elected to include just infants with CHD after CTS for a more homogeneous cohort. Third, this cohort included a small sample size of 20 patients in the final analysis. However, all patients had to have at least 30 documented scores, and the mean difference in the modified Finnegan and adjusted Finnegan was assessed via the trapezoidal method, with each patient serving as his or her own control. Another limitation is that the modified Finnegan is validated specifically for assessment of opioid withdrawal. Most patients were exposed to midazolam and/or dexmedetomidine in addition to opioid continuous infusions. Therefore, there is a possibility that elevated scores could have been

a result of multiple agents, but it is difficult to confirm this without a validated tool for all agents.

Another limitation was the application of the adjusted Finnegan. The adjusted Finnegan has not been validated for use in the clinical setting, and no threshold for pharmacologic intervention has been established. We found a significant mean difference in the AUC between the modified and adjusted Finnegan tools. However, we are not recommending use of the adjusted Finnegan tool for clinical application. Rather, this pilot study would suggest that future studies should be conducted to identify the most appropriate, validated tool to assess IOAS in infants ages ≥14 days in the NICU. Because we calculated the WAT-1 score retrospectively and made assumptions for the poststimulus portion of the WAT-1, we cannot with full certainty suggest that the WAT-1 be used in this population. We suggest a prospective study comparing the WAT-1 scoring tool versus the modified Finnegan while simultaneously scoring both tools using the patient as his or her own control.

Conclusions

The modified Finnegan is a commonly used tool in US NICUs to assess neonatal abstinence syndrome. However, the appropriateness of this tool when applied to infants >14 days with IOAS is unknown. An adjusted Finnegan score was calculated to demonstrate the difference between the modified Finnegan when newborn-specific factors were removed. There was a significant difference in the AUC between scores, 34.6 ($p < 0.001$). Because of emerging concerns regarding the impact of cumulative opioid exposure on neurodevelopmental outcomes in infants, it is imperative to use an appropriate scoring tool to guide medication therapy to limit opioid exposure. Overestimation of withdrawal scores could result in increased opioid exposure when it may not be indicated. The findings suggest that exclusion of certain neonatal criteria can influence the withdrawal scores. Although the adjusted Finnegan is not a validated tool that can be applied to practice currently, the variations demonstrate the need for further study. Specifically, future studies should focus on prospectively comparing validated scoring tools, like the WAT-1 versus modified Finnegan in older infants to determine potential differences.

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