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Revised Dose Schema of Sublingual Buprenorphine in the Treatment of the Neonatal Opioid Abstinence Syndrome

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Abstract

AIMS—Over half of infants exposed to opioids in utero develop neonatal abstinence syndrome (NAS) of severity to require pharmacologic therapy. Current treatments are associated with prolonged hospitalization. We sought to optimize the dose of sublingual buprenorphine in the treatment of NAS.

DESIGN—Randomized, phase 1, open-label, active-control clinical trial comparing sublingual buprenorphine to oral morphine.

SETTING—Large, urban, tertiary care hospital.

PARTICIPANTS—Twenty-four term infants requiring pharmacological treatment for NAS.

MEASUREMENTS—Outcomes were neonatal safety, length of treatment, and length of hospitalization.

FINDINGS—Sublingual buprenorphine was safe and effective. Infants treated with buprenorphine had a 23-day length of treatment compared to 38 days for those treated with morphine ($p=0.01$), representing a 40% reduction. Length of hospital stay in the buprenorphine group was reduced 24%, from 42 to 32 days ($p=0.05$).

CONCLUSIONS—Sublingual buprenorphine was safe in NAS, with a substantial efficacy advantage over standard of care therapy with oral morphine.

Keywords

Neonatal Abstinence Syndrome (D009357); buprenorphine (D002047); Sublingual Drug Administration (D000286); morphine (D009020); pediatric (D010372)

INTRODUCTION

Infants born to mothers receiving methadone maintenance often develop withdrawal symptoms in a complex known as the neonatal abstinence syndrome (NAS). NAS is

characterized by signs and symptoms of central nervous system hyperirritability, gastrointestinal dysfunction, respiratory distress, and autonomic symptoms. (1) Common symptoms in order of frequency include tremors, high-pitched cry, sneezing, increased muscle tone, regurgitation and vomiting, poor sleep, loose stools, sweating, excoriation, mottling, nasal stuffiness, low-grade fever, and tachypnea. NAS reflects a spectrum of disease, and those with milder symptoms respond well to supportive treatments. NAS symptoms severe enough to require pharmacologic treatment occur in 55-94% of infants born to opioid-dependent mothers. (1)

The optimal pharmacologic regimen for NAS has not been established, as reflected in the considerable heterogeneity in the diagnosis (2) and treatment (3,4) of NAS among different institutions. Treatments employed have included opioids, anticonvulsants, benzodiazepines, alpha 2 adrenergic antagonists, chloral hydrate, and the phenothiazine antipsychotic agent chlorpromazine. Cochrane reviews, (5,6) the American Academy of Pediatrics, (1) and expert review (7,8) identify opioid replacement as the ideal treatment for the withdrawal symptoms associated with in utero exposure to opiates. Morphine is the most commonly used agent, and is associated with treatment duration of 8-79 days, (9-14) almost always in an inpatient setting. The use of outpatient treatment in highly selected patients has been reported to be associated with shorter inpatient stays, but longer total duration of therapy. (15)

Buprenorphine is a long-acting partial mu opioid receptor agonist used in the treatment of adult abstinence therapy. It has the advantage of decreased abuse potential and less respiratory depression than other opioid agonists. We have previously reported the first use of sublingual buprenorphine in NAS at a dose of 13.2 mcg/kg/day in three divided doses. (16) Though designed as a phase 1 safety study, the investigation suggested reduction in lengths of treatment and inpatient hospitalization of approximately 30%. We report here on a separate, second cohort of 24 patients treated with a revised, dose-optimized treatment plan for buprenorphine.

METHODS

Study Design

This was a single site, randomized, open label trial. (Figure 1) Neonates were randomized to treatment with either sublingual buprenorphine or oral morphine in a 1:1 ratio. NAS was graded using the MOTHER NAS score, which is measured after feeding and is the standard instrument used in the multicenter NIH funded MOTHER study (ClinTrials.gov ID NCT00271219) of buprenorphine in pregnancy. (17) It is also the standard instrument at Thomas Jefferson University Hospital, and it administered by trained nurses. The MOTHER NAS score (hereafter "NAS score") is based upon the Finnegan score, (18) modifications of which are the most commonly used to monitor NAS. (4,19) Initiation of treatment was based on any consecutive 3 scores adding up to ≥ 24 or a single score ≥ 12 . Inclusion criteria included ≥ 37 weeks gestation, exposure to opioids in utero, and demonstration of signs and symptoms of NAS requiring treatment. Exclusion criteria were major congenital malformations and/or intrauterine growth retardation, (20) medical illness requiring intensification of medical therapy, concomitant maternal benzodiazepine (documented by history and urine toxicology) or severe alcohol abuse, maternal use of alcohol or of benzodiazepines in the 30 days prior to enrollment (as determined by self-report or intake urine drug screen), concomitant neonatal use of cytochrome P450 3A inhibitors or inducers prior to treatment, seizure activity or other neurologic abnormality, breast feeding or inability of mother to give informed consent due to co-morbid psychiatric diagnosis. The study was approved by the Institutional Review Board of Thomas Jefferson University.

Computer-generated randomization was performed by the hospital Investigational Drug Service.

Study Treatments

Patients randomized to sublingual buprenorphine initially received 15.9 mcg/kg/day in 3 divided doses. Buprenorphine solution was prepared by mixing buprenorphine for injection (Buprenex, Reckitt Benckiser) to a final concentration of 0.075 mg/mL in 100% ethanol USP (30% of total volume) and simple syrup USP (85 gm sucrose/100 ml). The solution was administered under the tongue followed by insertion of a pacifier to reduce swallowing. Dose escalation was a 25% increase for NAS scale scores ≥ 24 total on 3 measures or a single score of ≥ 12 . Patients with inadequate control between scheduled doses could be administered a rescue dose of 50% of the previous dose, after which the subsequent dose would be advanced 25%. After at least 3 days of dose stabilization, patients could begin weaning for scores < 8 . Weaning was at intervals of 10% daily, with no more than one weaning a day. Cessation of dosing occurred when buprenorphine was within 10% of the initial dose. All dose calculations were based upon birth weight. If NAS was not controlled at 60 mcg/kg/day, patients were administered phenobarbital 20 mg/kg load followed by 2.5 mg/kg twice a day for at least 2 days. Phenobarbital was discontinued prior to reduction of the opioid. When NAS scores were reliably < 8 , the daily dose of phenobarbital was reduced by 50%, followed by complete cessation as tolerated by scores. Cessation was generally 2 days following 50% dose reduction.

Standard of care treatment at Thomas Jefferson University Hospital consists of an initial dose of morphine 0.4 mg/kg/day in 6 divided doses with dose escalation of 10%/day for NAS scale scores ≥ 24 total on 3 measures or a single score of ≥ 12 . All dose calculations were based upon daily weight. When a patient required a rescue dose, an additional dose of morphine was administered. Adjunctive treatment with phenobarbital was initiated when the dose of morphine reached 1 mg/kg/day. Weaning from the phenobarbital was the same in both the buprenorphine and morphine groups. Infants were weaned with 10% dose reduction every 24 hours as tolerated until 0.15 mg/kg/day morphine was reached. All patients in the trial were observed for at least two days following the cessation of dosing.

Statistics

This was a follow up pilot study to optimize the dose of sublingual buprenorphine in neonates. Therefore, sample size was not based upon a formal power calculation. Group comparisons for continuous variables were made using the Mann-Whitney U test. Statistical analysis was completed with JMP 5.1.2 (SAS Institute Inc.). Analysis was performed on an intention to treat basis.

RESULTS

Twenty-four infants were enrolled between February 2008 and January 2010. Patient characteristics are presented in Table 1. All women were maintained on methadone at the time of birth. Infants were treated in the neonatal intensive care or step down unit.

Safety

A list of all adverse events observed in the trial is presented in Table 2. There was one serious adverse event in a patient randomized to buprenorphine. This infant had adverse events of cytomegalovirus (CMV) infection, prolonged reflux/poor feeding, elevated transaminases, aminoaciduria, and paronychia of a finger. Poor feeding and enteral hypomotility was initially thought to be part of NAS, but lack of resolution on buprenorphine and phenobarbital, and indeed no worsening when these drugs were removed

led to further medical evaluation. CMV was noted in urine, and a lack of cerebral calcifications or microcephaly at birth suggest a late in utero or possibly nosocomial infection. Length of buprenorphine treatment was 45 days and length of stay was 98 days. On the last day of buprenorphine weaning, alanine transaminase (ALT) was noted to be 30x the upper limit of normal (ULN), while aspartate transaminase (AST) was noted to be 20x ULN. These values waxed and waned over the remainder of the hospitalization, and remained elevated 6 weeks following the cessation of buprenorphine. Bilirubin was never elevated. The data safety monitoring board reviewed the case and came to the unanimous judgment that buprenorphine was not responsible for the clinical course of the infant, but did endorse our suggestion to monitor liver function for future enrollees. Liver function testing pre-dose, and at 7 and 21 days post randomization was normal in 6 subsequent patients (three in each treatment arm).

Efficacy

Infants treated with buprenorphine had a 23-day length of treatment compared to 38 days for those treated with morphine ($p=0.01$). (Table 3 and Figure 2) This represents a 40% reduction. Length of hospital stay in the buprenorphine group was reduced 24%, from 42 to 32 days ($p=0.05$). Three infants treated with buprenorphine required phenobarbital compared to one infant treated with morphine. No infant in the study was re-admitted for withdrawal following discharge.

DISCUSSION

This study builds upon our prior report describing the use of buprenorphine in the treatment of opioid NAS. In the initial cohort, an observation of an initial rapid up-titration, frequent attainment of maximum dose, lower than anticipated plasma buprenorphine levels, and lack of opioid toxicity led to a revision of dose that was employed in the currently described study. A strategy of dose optimization of increasing the 1) initial dose, 2) rate of dose up-titration, and 3) maximum daily dose was used. A formulation increase in drug concentration was used to maintain manageable drug volume for administration. Sublingual buprenorphine continued to maintain safety at these higher doses. In addition, there was continued advantage over morphine in length of treatment and length of stay, which was now statistically significant. It is arguable that many signs and symptoms observed in the infant with CMV infection did not reflect severity of NAS but instead were manifestations of the multiorgan viral process. Data from this infant was included in the primary analysis. However, removal of this infant causes the mean length of treatment to drop from 23 to 21 days, and length of hospital stay to drop from 32 to 26.

Three patients in the buprenorphine group required the use of adjunctive phenobarbital compared to one patient in the morphine group. Phenobarbital is often used as in cases of treatment failure. Specifically, this is a rescue therapy when maximum opioid replacement therapy dose is reached without adequate resolution of symptoms. It has also been used as an initial adjunct in combination therapy with an opioid (11) or as initial monotherapy. (21) Morphine and buprenorphine employ different up-titration rates and number of up-titrations until maximum dose is reached (6 for buprenorphine and 9 for morphine). Thus, it could be argued that the need for adjunctive phenobarbital is not necessarily a surrogate of "treatment failure" in infants who, independent of treatment allocation, have a more severe withdrawal symptom complex. Phenobarbital arguably has a therapeutic index similar to that of opioid treatment in this patient population. It is also not clear where on the dose response curve the present maximum buprenorphine dose lies. It is plausible that as a partial agonist, buprenorphine may not be able to induce the dense signal generation at the mu opioid receptor obtained with morphine. Alternatively, it could be hypothesized that a higher maximum dose of buprenorphine could reduce the frequency with which adjunctive

phenobarbital would need to be used. However, as there are no definitive adverse events associated with short-term exposure to phenobarbital, it is possible that a short course of phenobarbital may be a useful adjunct to reduce total duration of treatment in children with more severe withdrawal symptoms.

A mechanistic basis for the improvement of buprenorphine over morphine is not immediately clear. The longer duration of action and residence at the mu opioid receptor of buprenorphine relative to morphine may reduce the sudden shifts in receptor agonism and withdrawal symptoms. A more prolonged persistence of drug effect following cessation likely reduces symptoms. Two features of buprenorphine dosing compared to morphine also merit noting. Buprenorphine has a higher up-titration of dose compared to morphine (25 vs. 10%), which may allow a quicker attainment of symptom control. Though both regimens employ a 10% weaning schedule, buprenorphine is stopped when the dose is within 10% of the starting dose. In contrast, the initial morphine dose is 0.4 mg/kg/day, while cessation of dosing takes place only after the drug has been weaned to 0.15 mg/kg/day. Finally, the buprenorphine group dosing was based upon birth weight, while the morphine group was dosed according to daily weight. This difference serves to decrease a relative dose of buprenorphine as the infant grows.

This study was of an open label, randomized, design with primary goals of demonstrating safety and feasibility of sublingual buprenorphine. It is possible that there was occult bias in the scoring of infants by the nurse evaluators, despite the use of structured training sessions. A double blind, double dummy study would be required to fully evaluate any differential efficacy of buprenorphine over morphine. Another limitation is that the study excluded infants with benzodiazepine exposure and preterm infants. While these populations were excluded for safety reasons, they do limit the generalizability of results. Infants with in utero benzodiazepine exposure have a longer length of stay and treatment compared to those without. (14,22-24) Such patients represent a group in whom research should be directed. Premature infants typically have less severe NAS, (25) but buprenorphine does not have an established safety record in this population. Finally, while the length of treatment and length of stay noted in this study is consistent with observational data at Thomas Jefferson University Hospital between 2000-2006, (14) it is longer than has been noted at other institutions. (9,12,26,27) It is not clear if the magnitude of advantage over standard therapy would be maintained at institutions with a shorter length of stay. While features of buprenorphine may make its use in the outpatient treatment of NAS attractive, this has not been evaluated.

In conclusion, buprenorphine at an optimized dose schema has been demonstrated to be safe and efficacious in the treatment of NAS. While indications of a therapeutic advantage over morphine again have been demonstrated, these need to be verified in a double blind clinical trial. Additionally, the unique characteristics of buprenorphine make exploration of outpatient use for treatment of NAS a ripe area for clinical research.

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Figure 1.
Study Schema

Figure 2.
Length of Treatment and Length of Stay

Table 1

Characteristics of Patients in the trial

		Morphine	Buprenorphine
N		12	12
Sex	Male	4	6
	Female	8	6
Race	White, non Hispanic	11	12
	African-American	1	0
Birth weight (gm) //		2680 [SD 462]	3010 [SD 574]
Gestational Age (weeks) //		39.3	39.1
Onset of Treatment. Mean Days after birth //		2.4 [SD 0.89]	2.3 [SD 1.4]
1-Minute APGAR Score //		8.1	7.6
5-Minute APGAR Score //		8.9	9.0
Daily Maternal Methadone Dose (mg) //		124 [SD 60]	157 [SD 57]

// Mean

Table 2

Adverse Events

Treatment	Adverse Event	Serious AE	Causality
morphine	oral thrush	no	unrelated
buprenorphine	paronychia of finger	no	unrelated
	reflux/poor feeding	yes	probably not related
	elevated transaminases	no	probably not related
	Cytomegalovirus infection	no	unrelated
	aminoaciduria	no	unrelated
morphine	conjunctivitis	no	unrelated
morphine	oral thrush	no	unrelated
buprenorphine	clavicle birth fracture	no	unrelated
morphine	reflux	no	unrelated

Table 3

Efficacy Outcomes of Buprenorphine and Morphine (Mean)

	Buprenorphine	Morphine	p value
N	12	12	
Length of Treatment (days)	23 [SD 12]	38 [SD 14]	0.01
Length of Hospital Stay (days)	32 [SD 24]	42 [SD 13]	0.05
Phenobarbital adjunctive therapy (patients)	3	1	