Outcome of goal-directed non-invasive ventilation and mechanical insufflation/exsufflation in spinal muscular atrophy type I

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ABSTRACT

Background There are widely discrepant views on the respiratory management of infants with spinal muscular atrophy (SMA) type I. Typically, management is palliative.

Design A descriptive study of interventions and investigations is reported that were offered to a cohort of 13 children with SMA type I referred to our centre.

Interventions and investigations included sleep studies, provision of non-invasive positive pressure ventilation (NIPPV) for ventilatory support/dependency and for physiotherapy and the use of mechanical insufflation/exsufflation (MI-E).

Results NIPPV was provided for the following indications: continuous positive airways pressure flow driver dependency (n=3), nocturnal hypoventilation (n=3), to enable successful extubation (n=2), in anticipation of respiratory decompensation (n=3), and oxygen dependency/decompensation (n=2). NIPPV and MI-E were used for successful protocol-led extubations (n=9) but not non protocol-led successes (n=3). NIPPV was essential for discharge home in patients with ventilatory dependency (n=7) and was used for palliation of respiratory symptoms (n=4). Chest wall shape improved with NIPPV. The parents of children who died (n=5) were positive about the use of these techniques.

Conclusion NIPPV can be used to facilitate discharge home, and MI-E is helpful in this group. This symptom and goal-directed approach can be used to inform medical decision making and to help parents make informed choices about the appropriateness of respiratory interventions in SMA type I.

What is already known on this topic

- Respiratory management in spinal muscular atrophy (SMA) type I is controversial.
- Recent studies have shown increased survival in SMA type I with ventilation and mechanical insufflation/exsufflation.

What this study adds

- This study reports the experience of a UK specialist centre in initiation and management of home non-invasive positive pressure ventilation (NIPPV) in SMA type I infants, who would not previously been offered this as a treatment of choice.
- This study highlights the role of NIPPV to palliate symptoms of respiratory distress in infants and the importance of advance care pathways.

Spinal muscular atrophy (SMA) is an autosomal recessive disease of varying severity caused by mutations in the SMN1 or VAPB genes resulting in loss of alpha motor neurons in the anterior horn of the spinal cord and secondary muscle atrophy. SMA is classified by functional categories: SMA type I (Werdnig–Hoffman disease), children never attain independent sitting; SMA type II, children attain independent sitting but cannot walk unaided and SMA type III, children attain the ability to walk unaided.[1] In the UK, between 2006 and 2008, 22–24 families per year with infants newly diagnosed as having SMA type I sought support from the Jennifer Trust for Spinal Muscular Atrophy (J Doubtfire, personal communication, 2009). This is likely to be an underestimate of the number of children diagnosed as having the disease in the UK because not all families seek support.

SMA type I is typically characterised by profound global weakness, which may be evident at birth or even antenatally, manifest by reduced fetal movements. Early respiratory failure is the major cause of morbidity and mortality in SMA type I,[2] and most children do not survive beyond 2 years of age[2 3] without specialised treatment. However, there are reports of prolonged survival with the addition of tracheostomy positive pressure ventilation, non-invasive positive pressure ventilation (NIPPV), mechanical insufflation/exsufflation (MI-E) and supplementary feeding.[4–6] Oskoui *et al*[6] showed that survival of children with SMA type I from the international SMA register born in 1995–2006 has increased compared with those born in 1980–1994 (median survival 24.0 vs 7.5 months, respectively). Within the total group, those children who died presented with earlier onset of weakness and hypotonia (mean (SD) 2.0 (1.5) versus 3.3 (1.7) months for those who were alive). Their survival probabilities in 1995–2006 versus 1980–1994 were 79% versus 37% at 12 months and 74% versus 31% at 24 months. The authors concluded that this was due to more patients receiving ventilation (82% vs 31%), MI-E (63% vs 8%) and supplementary feeding (78% vs 40%).

Typically, children with SMA type I will develop a significant chest wall deformity. The typical pattern of respiratory muscle weakness in SMA is intercostal muscle weakness with relative sparing of the diaphragm.[7 8] This gives rise to a characteristic pattern of paradoxical breathing and pectus excavatum.[9] Chest wall deformity has also been shown to improve with high-span (pressure support >14 cm H_2O) NIPPV.[9]

The approach to assisted ventilation in SMA type I is very variable.[10] Overall, NIPPV was offered and recommended by 70%, offered but not recommended by 22.5% and neither offered nor recommended by 7.5% of physicians. Forty-two per cent of intensivists, 62% of neurologists and only 2% of physiatrists (rehabilitation doctors in the USA) agreed with the statement that "SMA type I is a fatal condition and NIPPV during a respiratory illness just prolongs death as a result of respiratory failure".

Recently, the Jennifer Trust for Spinal Muscular Atrophy, UK commissioned a workshop to review the international statement on the standards of care in SMA[11] with specific reference to the management of infants in the UK with severe form of SMA type I.[12] This document does not address care of infants with non-severe SMA type I (ie, those who present with hypotonia after 3 months of life). There are no randomised, controlled trials in this patient group, so the level of evidence is case series only. We, therefore, report our experience of the respiratory management for all patients with SMA type I, together with outcomes, in this descriptive cohort study. The aim is to inform medical teams of the options available for these infants, so they can help parents make truly informed choices about the appropriateness of referral and management plans.

METHODS

All patients with SMA type I who were referred to us after 1993 were identified from a case registry. Demographic data were extracted from patient medical records. All patients underwent overnight oxygen saturation (SpO_2) monitoring and transcutaneous carbon dioxide ($TcCO_2$) monitoring. SpO_2 and $TcCO_2$ were monitored by a Nellcor N200 pulse oximeter (Tyco, Gosport, UK), and $TcCO_2$ was also measured using TINA TcCM CO_2 electrode (TCM3; Radiometer, Copenhagen, Denmark). Nocturnal hypoventilation was defined as $TcCO_2$ >6.5 kPa for more than two-thirds of the night (standard protocol for diagnosis of nocturnal hypoventilation at our centre).[13] Patients were treated with NIPPV to correct nocturnal hypoventilation, reverse observed paradoxical breathing and facilitate airway clearance during physiotherapy. Patients who were referred because of flow driver continuous positive airways pressure (CPAP) or oxygen dependency were stabilised and transferred onto NIPPV.

Likely outcomes were discussed with all parents as appropriate to the severity of their child's condition. These included three management goals: (1) optimal medical management (physiotherapy to clear respiratory secretions, consideration of hyoscine and glycopyrronium for excess oral secretions and oxygen and opiates for respiratory distress; (2) use of NIPPV either to palliate symptoms of respiratory distress or to correct nocturnal hypoventilation and (3) use of tracheostomy. All management options were discussed, and the parents were given time to reflect and decide what was the best option for their child and the family unit. We informed families that NIPPV or tracheostomy intermittent positive pressure ventilation (TIPPV) was unlikely to prolong life in severe SMA type I (diagnosed before 3 months). In our patients, we provided NIPPV for these families with the aim of palliating symptoms for the child and facilitating discharge home with a palliative care package. In those children in whom SMA type I was diagnosed after 3 months of age, it was explained that NIPPV may increase survival and would correct nocturnal hypoventilation.[14]

Initiation of NIPPV

All infants were initially managed with a nasal mask (infant mask system, large and small infant bubble cushion (ResMed, Abingdon, UK); small child's Profile lite and petit (Profile Lite; Philips Respironics, Bognor Regis, UK). The nasal mask allowed secretions to be easily cleared from the mouth. Infants were only swapped to a full-face mask if optimal ventilation could not be achieved with a nasal mask. In infants acclimatising to NIPPV, pressures were set low (inspiratory positive airways pressure (IPAP) 12 cm H_2O, expiratory positive airways pressure (EPAP) 4 cm H_2O with a backup rate between 18 and 35 breaths per minute depending on the child's spontaneous respiratory rate and inspiratory time); settings were then rapidly increased to ensure good thoracic cage movement and eliminate paradoxical breathing.[15] A minimum EPAP of 4 cm H_2O was set to prevent rebreathing of CO_2 with the bilevel ventilator leak circuit used. Settings were also adjusted to correct nocturnal hypoventilation.

Extubation onto NIPPV

We also evaluated our protocol-led extubations.[16] Patients who had been intubated as a result of a reversible event (acute respiratory tract infection) were extubated to NIPPV. Before extubation, all patients were stable with normal arterial oxygen saturation and carbon dioxide tension while ventilated on air. We ensured that all patients were able to be ventilated on room air to ensure that there was no suggestion of excess bronchial secretions or atelectasis still being present. If the patient still required oxygen therapy to maintain an arterial oxygen saturation level of >95%, they were treated intensively with physiotherapy and MI-E (Cough assist; Phillips Respironics, Murrysville, Pennsylvania, USA) until they were secretion-free and stable. We also ensured optimal ventilator settings on the patient's own NIPPV ventilator by attaching it to the endotracheal tube and reviewing their oxygen and carbon dioxide tensions. Patients were extubated onto their normal non-invasive mask. However, if there were difficulties with mask leak and inadequate chest wall movement, a full-face mask was used. When indicated, gastro-oesophageal reflux was treated, and glycopyrrolate was administered to reduce oropharyngeal secretions. After extubation, standard care included enteral feeding, intensive NIPPV, MI-E combined with an airway clearance session of intermittent clapping, manual assisted coughing and nasopharyngeal suction. We encouraged regular airway clearance treatment rather than just entraining oxygen when oxygen saturation decreased below 95%. However, supplementary oxygen was added to maintain oxygen saturation while providing airway clearance techniques if required.

Physiotherapy and MI-E

Families were encouraged to carry out daily airway clearance sessions to ensure that there were no retained secretions and to maintain familiarity with the techniques. They were advised

that airway clearance be performed when oxygen saturation decreased below 95% rather than adding oxygen supplementation. We carefully explained that arterial oxygen desaturation is likely to be due to excessive secretions and should resolve with airway clearance. Physiotherapy consisted of chest clapping and nasopharyngeal suction carried out with the assistance of the NIPPV. In children older than 3 years, abdominal assisted cough technique was taught because the patients at this age are able to cooperate with cough techniques. MI-E was provided for patients in whom physiotherapy described previously became ineffective or when treatment duration became excessive (>30 min). MI-E was carried out in manual mode with fast MI-Es; initial pressures were +30 to −30 cm H_2O. Settings are then increased until good thoracic wall expansion is noted; negative pressure is increased until good secretion clearance occurs. Where possible, for discharge and ease of use, settings for home were adjusted to automatic mode and used as required.

Before discharge home, all parents underwent comprehensive teaching and respiratory care competency sessions. This training was also offered to the community teams looking after these infants. Before discharge, a written advanced care plan was formulated in partnership with the parents and the medical team. Information was then disseminated to all involved in the infant's care, including the ambulance service. Typical information included whether the patient should be resuscitated, and this also included the situations that this was appropriate; whether they were to be intubated and ventilated in the event of an acute reversible event, for example, sputum plug (transient intubation) and whether nasogastric or percutaneous gastronomy tube feeding should be part of the care package. Parental views on TIPPV were also incorporated and preferences on what they would wish to happen if their infant was intubated and ventilated for a prolonged period but was continuing to deteriorate.

Where possible, lateral- and frontal-view photographs of the thorax were taken. These images allowed us to monitor any progression or regression of chest wall deformities.

If the child died, we asked families to feed back openly, and not in the form of a structured questionnaire, their experience of non-invasive ventilation and their views on the benefits versus the burden of care.

RESULTS

Fifteen patients with genetically confirmed SMA were referred. One infant died before transfer, and the family of one patient declined any ventilatory support, leaving 13 infants (eight males)—11 with SMA type I and 2 with borderline SMA type I/II (attained independent sitting only for <2 s)—as the subject of this report. All infants presented with hypotonia, and none had swallowing problems, behavioural issues or contractures at diagnosis. The mean age at SMA diagnosis was 7.5 months (range 3–18 months); the median age at respiratory presentation was 11 months (range 4–24 months; table 1). Five patients were referred by their local hospital and three by a specialist neurology centre; four were referred at the request of parents. The reasons for referral included CPAP flow driver dependency (n=3), being part of an anticipatory care plan (n=3), nocturnal hypoventilation (n=3), weaning from mechanical ventilation (n=2), recurrent chest infections requiring oxygen therapy (n=1) and acute respiratory decompensation (n=1). Five patients died; two of these infants with a presentation of respiratory failure at 4 months died before a year of age. All infants who have presented late (after 10 months of age) have had a better prognosis. All patients who were referred to our centre for weaning from flow driver CPAP were successfully discharged home with NIPPV. Tracheostomy was discussed but declined in all cases.

Table 2 provides information on advance care plans. Of 17 episodes of intubation were because of respiratory failure, three were successfully extubated with a non protocol-led approach and nine with a protocol-led approach; one of the five other children died as a result of failed extubations, and two children were re-intubated and transferred to us for our protocol-led extubation (table 2). Thirteen infective exacerbations were managed non-invasively in this group. Six of 13 patients used NIPPV to control sleep-disordered breathing, and two patients were given NIPPV pre-emptively for use during respiratory tract infections. The remaining patients required daytime use in addition to nocturnal use. In most of the patients, the daily duration of NIPPV use has increased over time.

Patients used a variety of non-invasive ventilators. All ventilators were bilevel and used in spontaneous/timed mode. Where possible, infants were given NIPPV with a nasal mask, and this was successful in 11 of 13 patients. Initial IPAP was

Table 1 Patient demographics

Patient	SMA classification	Age at diagnosis (months)	Sex	Age at respiratory presentation	Supplementary feeding commenced (months)	Bulbar problems from birth	Normal intellect	Baseline mean SpO2 (%)	Baseline mean TcCO2 (kPa)	Peak TcCO2 (kPa)	Respiratory support during sleep study
A	SMA type I	4	Female	10 Months	10	N	Y	89	5	6	CPAP
B	Borderline type I/II	18	Male	24 Months	16	N	Y	97	5	7	CPAP
C	SMA type I	3	Male	4 Months	5	N	Y	88	7	14	SV
D	SMA type I	3	Female	6 Months	Not commenced	N	Y	97	5	5	SV
E	SMA type I	7	Male	10 Months	11	N	Y	95	8	14	2L NS
F	SMA type I	5	Male	18 Months	46	N	Y	97	5	6	SV
G	SMA type I	14	Male	14 Months	26	N	Y	97	6	6	NIPPV
H	SMA type I	3	Male	4 Months	4	N	Y	96	6	8	SV
I	SMA type I	7	Male	18 Months	28	N	Y	94	5	5	SV
J	Borderline type I/II	14	Male	19 Months	93	N	Y	97	6	7	SV
K	SMA type I	5	Male	6 Months	6.5	N	Y	94	6	7	NIPPV
L	SMA type I	10	Female	12 Months	19	N	Y	99	5	6	SV
M	SMA type I	5	Female	11 Months	13	N	Y	98	5	6	SV

CPAP, continuous positive airways pressure; N, no; NIPPV, non-invasive positive pressure ventilation; NS, nasal specs; SMA, spinal muscular atrophy; SpO_2, oxygen saturation; SV, self-ventilating on room air; $TcCO_2$, transcutaneous carbon dioxide saturation; Y, yes.

Table 2 Ventilation characteristics

Patient	Resuscitation status: for intubation and ventilation?	Total number of intubations	Referred for management to facilitate discharge	Non protocol-led extubation success	Protocol-led extubation success	Admissions managed with non-invasive aids	Home mechanical insufflation/exsufflation?	NIPPV use at discharge after initiation	NIPPV use at present or before death
A	Y	3	Y	0	2	2	Y	Nocturnally	Nocturnally
B	Y	1	Y	0	1	0	N	Nocturnally	24 h a day
C	N	0	Y	NA	NA	0	N	18 h a day	24 h a day
D	Y	2	N	0	Not attempted	0	N	Acclimatisation to NIPPV	Nocturnally
E	Y	0	Y	NA	NA	2	Y	18 h per day	16 h per day
F	Y	0	N	NA	NA	2	Y	Acclimatisation to NIPPV	Nocturnally
G	Y	2	Y	1	1	2	Y	Nocturnally	Nocturnally
H	N	0	N	NA	NA	0	N	Nocturnally	23 h per day
I	Y	2	N	1	1	0	Y	Nocturnally	16 h per day
J	Y	2	N	1	1	2	N	When unwell with a respiratory tract infection	Nocturnally
K	N	0	N	NA	NA	1	Y	18 h a day	20 h per day
L	Y	1	N	0	1	1	N	Acclimatising to NIPPV	Nocturnally
M	Y	4	Y	0	2	1	Y	Nocturnally	Nocturnally

N, no; NA, not applicable; NIPPV, non-invasive positive pressure ventilation; Y, yes.

12 cm H_2O with EPAP of 4 cm H_2O in all patients. IPAP was titrated to treat hypoventilation with a median IPAP of 18 cm H_2O. The backup rate was between 18 and 35 breaths per minute. All ventilators were lightweight, were portable and could be battery operated.

Twelve of 13 patients required supplementary feeding via nasogastric tube or percutaneous gastrostomy (table 1). No patient had any problems with supplementary overnight feeding during NIPPV.

Seven children required MI-E at home (table 2). Indications for the addition of MI-E were either or both of increased length of time to carry out physiotherapy due to tenacious secretions and increased episodes of sputum plugging. Where possible, mechanical cough assistance was introduced in a period of stability for the infant to acclimatise to the device. Only one patient needed it to ensure a safe discharge. The median age at initiation of MI-E was 13 months (range 10–43 months). Typical MI-E pressure span was +25 to −30 cm H_2O, increasing to +35 to −45 cm H_2O as clinically indicated.

Figures 1A and B show photographs of chest wall profile in two of the patients. No infant given NIPPV subsequently developed pectus excavatum, confirming a previous report.[9] Figure 1A shows an infant who was given NIPPV early and who, with continued use of NIPPV, did not develop a chest wall deformity. Figure 1B shows an infant with a chest wall deformity present at referral. This infant had a gastrostomy feeding tube inserted, but despite improved nutritional status for 6 months, there was no improvement in the chest wall deformity; he then was given nocturnal NIPPV, and after 6 months, there was a significant improvement in the chest wall profile.

The parents of the five infants who died gave their views and experiences on the use of NIPPV via informal feedback and not in the form of a structured questionnaire. All reported that their child's breathing appeared more comfortable with ventilatory support. Parents reported that NIPPV enabled them to have family time with their child at home, which would not have been possible in the hospital environment. One family commented that the extra period at home gave them the opportunity to come to terms with the diagnosis and prognosis, which they felt would not have been possible if their child had died in the intensive care unit.

DISCUSSION

This is the largest sequential case series describing the respiratory management of children with SMA type I in the UK. The goal-targeted approach of using NIPPV predominantly to control symptoms and facilitate care at home has meant that parents are offered an informed choice about the management of their child. We are not aware of other centres in the UK successfully using NIPPV to palliate respiratory symptoms in children with SMA type I who present at a very early age or in those who present after invasive ventilation after acute respiratory decompensation. We have also shown that this intervention has enabled infants with early presentation of SMA type I to be discharged home from hospital to have quality time in their home with their families.[4 17 18] This provides the family with choices and may assist them in coming to terms with the terminal diagnosis. In our group of patients with later presentation, we also found improved survival,[6 16 19] so it is notable that in some cases, NIPPV can ameliorate symptoms while at the same time extending life.

In infancy, our patients required multiple hospital admissions, but as they grew older, the frequency of admissions decreased.[16 19] In six long-term survivors, there were 23 admissions (7.6/year) in the first 3 years of life but only seven admissions in total after the age of 3 years (0.2/year). We adopted a protocol-led management programme to try to prevent intubation. If intubation was required, we aimed to extubate to NIPPV. By following a protocol in a specialist centre, this group of children can be successfully extubated.

Parents and carers of children with SMA are often well informed about developments in medical management. They may be aware that not all hospitals have the resources to offer NIPPV during an acute respiratory tract infection. By teaching the parents and acclimatising children to the use of NIPPV, they will be ready to use it as and when required.

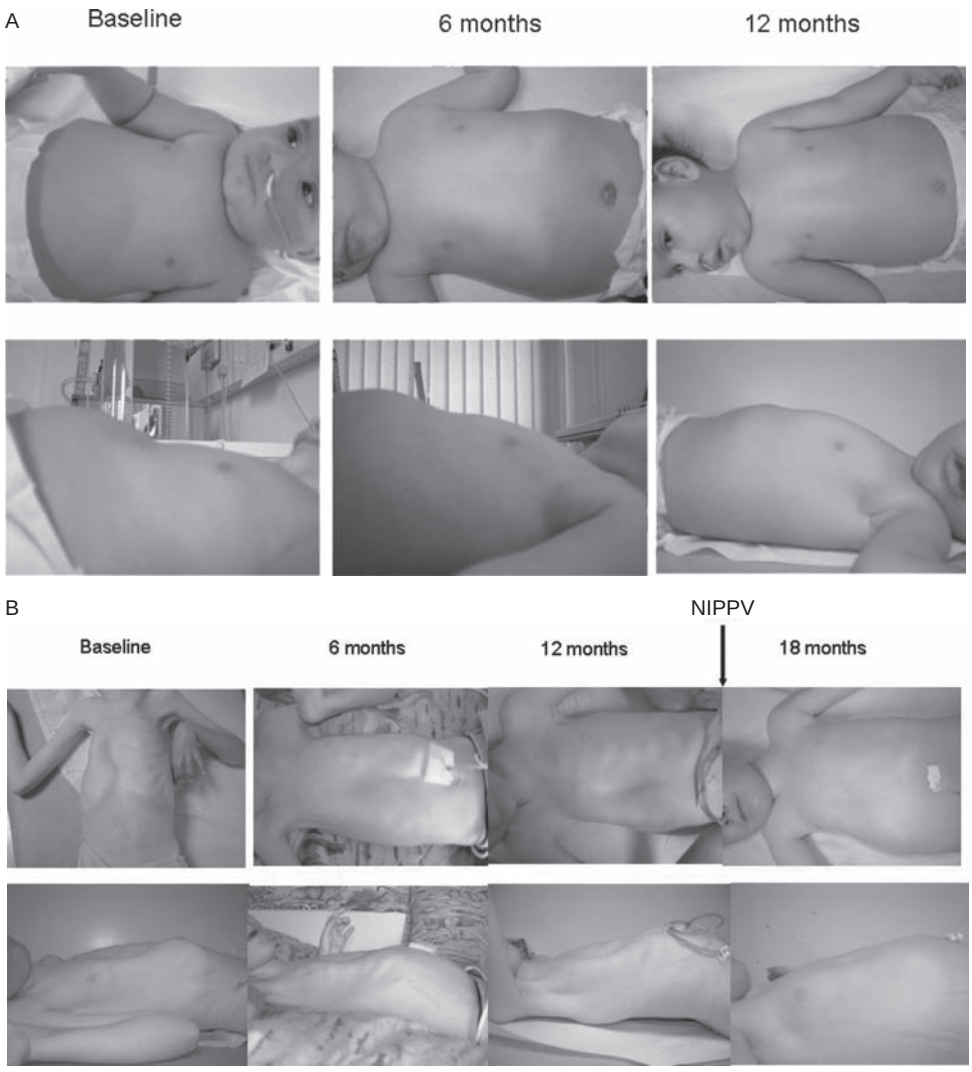

Figure 1 (A) Chest wall photographs at baseline, 6 months and 12 months in an infant who commenced non-invasive positive pressure ventilation early; with continued use of NIPPV, there was no chest wall deformity. (B) Chest wall photographs at baseline, 6 months, 12 months and 18 months in an infant with a chest wall deformity present at referral. This infant had a gastrostomy feeding tube inserted, but despite improved nutritional status for 6 months, there was no improvement in chest shape; nocturnal NIPPV was commenced; after 6 months, there was a significant improvement in chest shape. NIPPV, non-invasive positive pressure ventilation.

Yates *et al*[20] confirmed that there might be a role for NIPPV preventing readmission to the paediatric intensive care unit. In our children with SMA type I, we found that at about 12–18 months of age, they began to have increased difficulty with sputum clearance. Around this age, we provide these children with MI-E devices. Also, as the children grow older, they have a greater understanding and ability to coordinate with MI-E devices and other physiotherapy techniques. This may be one explanation for the decrease in hospital admissions with age that we have seen and that has been previously reported.[19]

Once NIPPV was begun, any pectus excavatum resolved and no new case developed.[9] We speculate that pectus excavatum in the context of neuromuscular disease could lead to areas of hyperinflation and also areas of collapse, which can lead to ventilation perfusion mismatch.[21]

Abdominal bloating can be a problem because of disproportionate expiratory muscle weakness and reduced anterior abdominal muscle strength. In our patients, low EPAP (4 cm H_2O) and IPAP between 14 and 20 cm H_2O with a high back up rate (>20 breaths per minute) were well tolerated with a low reported incidence of bloating. We experienced very few problems when initiating patients on NIPPV. Our main concern was to ensure that the initiation of NIPPV did not cause secretions to be moved into the main airway and cause a large airway obstruction. Initiation of NIPPV was always in the acute hospital setting.

Previous studies have shown that medical professionals' perception of a patient's quality of life is often reported lower than that of parents or healthcare team members working closely with the patient.[22–24] There are also reported discrepancies between intensivists, physiatrists and neurologists in the respiratory management of SMA type I.[10] These differences mean that the provision of care in this group of patients varies from specialty to specialty and region to region. Our data confirms the improvement in prognosis in SMA type I[6] and the differing and important roles of NIPPV in this patient group, especially as current guidelines for the general management of SMA do not focus specifically on SMA type I.[11] Interestingly, a number of referrals of infants with SMA type

I to our centre were at the parent's request, often after surfing the internet.

These results are from a tertiary care hospital with an experienced multidisciplinary team. We recommend that children with SMA type I whose parents would like a respiratory opinion are referred to an experienced centre to discuss the treatment options. In some cases, ventilatory support will be inappropriate, whereas in others it may palliate symptoms of respiratory failure so that discharge home is possible for a short period. Others with SMA type I will see an improved survival. If these children are intubated, then a protocol-led approach to extubation is of benefit.[16] Because not all hospitals have MI-E to enable a protocol-led approach to extubation or to prevent intubation, we recommend in line with other reports that these patients have their own MI-E device.[4 16 25]

Ioos *et al*[4] reported survival data from France in SMA. The authors split SMA type I into true type I (children with onset before the age of 3 months and never able to raise their head) and intermediate type I (symptoms between 3 and 6 months and with the ability to raise their head) and applied a management programme described in previous articles from their unit.[26 27] To make comparison with the current literature, we have used the same classification. Two of our infants have true SMA type I, and like Ioos *et al*,[4] we did not show any increase in survival beyond the natural history of the disease. However, we were able to initiate NIPPV effectively to palliate symptoms of respiratory distress, enabling one of these infants to be discharged. In one infant who before initiation of NIPPV had restless sleep, the parents reported a significantly better sleep quality with NIPPV. One reason for our success may be that we commence NIPPV early in these infants with true SMA type I before the development of significant bulbar weakness. Possibly, bulbar weakness was less severe than in those infants with true SMA type I reported by the French group.[4] We also commence supplementary enteral feeding early to prevent aspiration. Ventilation practice differs between France and the UK, and it may be that by following the same protocol, the same results are seen regardless of country. The deaths of four of our patients were as a result of a respiratory tract infection as seen in other centres.[4 16] One patient died suddenly and unexpectedly without a clear cause; this has also been documented by others.[4 16] TIPPV was discussed with all parents, and no parent requested that NIPPV should be converted to TIPPV. The obvious advantage of nasal ventilation is that the infant's face is free of a mask during the day, and the nasal mask can be used for longer periods as the disease progresses.

Unlike Ioos *et al*,[4 16] none of our patients went on to receive TIPPV. Our patients remained stable on NIPPV and were able to clear secretions with the initiation of MI-E. Fifty-seven per cent of patients in the French cohort deemed to have intermediate SMA type I required TIPPV. A likely explanation for this is difficulty in clearing secretions. Their patients did not have MI-E devices. Despite no patient receiving TIPPV, TIPPV was discussed with all parents, and no parent requested that NIPPV be converted to TIPPV. The obvious advantage of nasal ventilation is that the infant's face is free of a mask during the day, and it can be worn for longer periods as the disease progresses. Speculative reasons for rejection of tracheostomy are that care packages for TIPPV can be more intrusive. TIPPV is also likely to lead to the infant with true/severe SMA type I becoming "locked in" or that the infant will no longer be able to phonate or make sounds because of profound weakness of the bulbar muscles, rendering a speaking valve of little value. All our patients attained the ability to cry/speak, although the quality was variable depending on the disease severity; current ventilatory free time is also variable (table 2). Reasons for non-utilisation of TIPPV may also be related to the beliefs and experience of the care team. TIPPV may limit socialisation because attendance at school can be difficult although not impossible, especially because these children are candidates for normal schooling with the appropriate physical support. The discussion about TIPPV is not straightforward and should be directed towards what is in the best interests of the child and their family.

There are limitations to our work, which must be acknowledged. The data is observational and anecdotal. However, unfortunately, there are no clinical trials of respiratory support strategies in this condition, and it is difficult to see how these could be designed ethically. Survival has certainly improved over time, but the use of historical controls is unsatisfactory.

In conclusion, we report that provision of NIPPV has a role in the respiratory management of SMA type I. NIPPV can be used to facilitate discharge home and may increase life expectancy, in part by allowing effective treatment during acute respiratory tract infection. MI-E has also allowed these children to be managed at home and in some cases may have prevented the need for intubation and invasive ventilation.

Finally, it is important to have advance care plans, so crucial decisions on interventions and whether escalation in ventilatory support are desirable can be made in a considered manner, and not at the time of acute decompensation.

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