

## Feeding tube securement in critical illness: Implications for safety.

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## Abstract

**Background:** Over 50% of tape secured feeding tubes are inadvertently lost.

**Aims:** Determine the impact of nasal bridle securement on tube loss, outcome and duration of use and potential complications.

**Methods:** Observing the effect of nasal bridle securement on nasogastric (NG) and nasointestinal (NI) tube loss from 01.10.2014 (NG) and 01.01.2010 (NI), respectively, to 31.12.2017.

**Findings:** Use of nasal bridles was independently associated with reduced NI (and NG) tube loss 36.9% to 11.8% (odds ratio, [OR]: 95% confidence interval [CI]: 0.2: 0.12-0.33,  $p < 0.0001$ ), increased duration of tube use (OR: 2.2 days, 95%CI: 0.8-2.9,  $p = 0.004$ ) and increased likelihood of tubes being used until no longer needed (18.1% to 33.8%, OR: 2.3, 95%CI: 1.6-3.3,  $p < 0.0001$ ). In a single-room ICU, tube loss dropped from 53% to 9% and tube redundancy (no longer required) rose from 20% to 64%.

**Conclusions:** UK-wide bridle securement could reduce premature tube loss need for replacement by 40% and could be associated with 1422 fewer pneumonias or pneumothoraces and 768 fewer deaths.

21

## 22 Running title

23 Tube securement: Safety implications.

24

## 25 Keywords

26 Nasal bridle; feeding tube; inadvertent, loss, safety; securement.

27

## 28 What is already known

- 29
- Most feeding tubes are lost to inadvertent patient removal or slippage.
- 30
- Nasal bridles reduce tubes loss and increase delivery of goal nutrition.

31

## 32 What this paper adds

- 33
- Use of nasal bridles is independently associated with reduction of inadvertent tube loss and this
- 34
- appears to increase the number of tubes reaching redundancy.
- 35
- By obviating the need for tube replacement, nasal bridle use may reduce risk of tube-related
- 36
- complications by 40%; this potentially translates into more than 1400 fewer major complications
- 37
- and deaths in the UK.

## 38 Acknowledgements

39 We thank the nursing, medical and dietetic ICU staff for making this study possible.

## 40 Conflict of interest

41 ST: Involved in developing a new nasal bridle with no commercial connection to the one used in the  
42 current study.

43 Other authors: None.

## 44 Ethics

45 The study observed standard practice and therefore did not require ethical approval.

## 46 Financial support

47 None.

## 48 Authorship contributions

49 ■ Conception and design of the study (ST), the acquisition of data (ST, KA), or the analysis (DT, ST)  
50 and interpretation of the data (All).

51 ■ Drafted or provided critical revision of the article (All).

52 ■ Provided final approval of the version submitted for publication (All).

## 53 Introduction

54 In the UK 790,000 naso-enteral tubes are purchased each year [NHSI. 2016]. However, in ICU 54% of tubes  
55 are lost to inadvertent patient removal and slippage with at least 44% requiring replacement [Taylor et al.  
56 2014a]. Risk from tube loss and replacement depends on how accurate tube guidance and confirmation are  
57 and the frequency of misplacement.

58

59 X-ray and pH are the most common methods to confirm feeding tube position, but both methods often fail. X-  
60 ray misinterpretation is the single most common cause of serious harm (45-47%) resulting from feeding  
61 through a misplaced tube [NPSA. 2011; NHSI. 2016]. Similarly, using colorimetric strips, 12% of pH 6.0  
62 samples are mis-identified as reaching the UK critical pH of 5.5 [Clemente and Taylor. 2016]. In rare cases,  
63 such as tonsillar squamous cell carcinoma, lung aspirates of pH 4.5-5.5 occur [Sellers. 2012]. In addition,  
64 using a threshold of 5.5 carries a 50% risk of identifying tube position as gastric when it is oesophageal [Ni et  
65 al. 2014]; oesophageal placement occurs in 20% of blind placements, so using a pH threshold of 5.5 would  
66 result in 10% being fed into the oesophagus. Undetected tube misplacements result in approximately 20  
67 cases of serious harm, including 4 deaths, per year in the UK [NHSI. 2016]. However, 1.5% of blindly placed  
68 tubes are misplaced into the respiratory tract, 0.5% resulting in pneumonia or pneumothorax [Taylor. 2018].  
69 Harm from oesophageal misplacement is unknown. These much more common complications cannot be  
70 prevented by an end-of-procedure pH test or X-ray [Taylor. 2013].

71

72 Reducing the pH threshold from 5.5 to 4.0 would reduce placement errors from 9.4% to 0.6% and but  
73 increase the need for X-ray confirmation from 24% to 34% [Ni et al. 2014]. This, the restriction of X-ray  
74 interpretation to senior Radiologists and a ban on overnight placement [NPSA. 2011] was associated with an  
75 8-9h delay to feed and drugs [Brazier et al. 2017]. These changes also increased the delay before feeding  
76 after nasogastric (NG) tube (re-)placement (median: 5.3h [IQR: 2-9] to 10 [6-16],  $p = 0.028$ ), increased the  
77 energy deficit per NGT (re-)placement (Kcal: 402 to 768,  $p = 0.04$ ) and per enteral nutrition episode (Kcal:  
78 2423 to 5660,  $p = 0.00024$ ) and reduced the nutrition goal delivered (84% to 71%,  $p = 0.018$ ) [Segaran et al.  
79 2015]. Finally, placement-associated complications are related to placement frequency, therefore if tube  
80 securement reduces preventable loss there could be a proportionate reduction in risk.

81

82 We determined associations between bridle use and inadvertent (patient or slippage) feeding tube loss and,  
83 for NI tubes, all causes of tube loss and the likelihood of tubes reaching redundancy. Based on these  
84 findings and published tube placement risk, we estimated the safety implications of bridle placement.

## 85 **Methods**

### 86 ***Study design***

87 Nasogastric tube loss data was collected, prospectively, as part of a 'device loss' audit from 1.10.2014 to  
88 31.12.2017 and compared per patient admission and ventilated day. Nasointestinal tube loss, reason for loss  
89 and duration of use were collected prospectively from 1.1.2010 to 31.12.2017 from the 'bedside NI tube  
90 placement service' audit.

91

### 92 ***1.1 Bridle use***

93 In May 2014 two predominantly open ward ICUs were merged into an ICU with single-patient rooms. From  
94 01.11.2014, a policy of fitting AMT™ nasal bridles to NG tubes was gradually introduced, as staff were  
95 trained, if one tube had been inadvertently removed by a patient, the tube was difficult to place or was a vital  
96 feed and/ or drug route. For NI tubes, all were fitted with bridles immediately after tube placement from  
97 01.1.2015.

98

### 99 ***Analysis***

100 We determined the effect of bridle securement on NG and NI tube loss and the potential impact on UK-wide  
101 safety. Parameters did not have normal distribution (Shapiro-Wilk test) therefore univariate analysis was  
102 carried out using Mann-Whitney signed-rank and Fisher's exact test using 'R Studio' v1.1.383. Because  
103 groups were dis-similar, age, acute physiology and chronic health evaluation (APACHE) 2 score, height,  
104 weight, disease category, conscious state, airway and days from ICU admission were entered into linear or  
105 logistic regression models. Independent variables with a p-value < 0.1 were retained and associations re-  
106 tested including 'bridle use'.

107

## 108 Findings

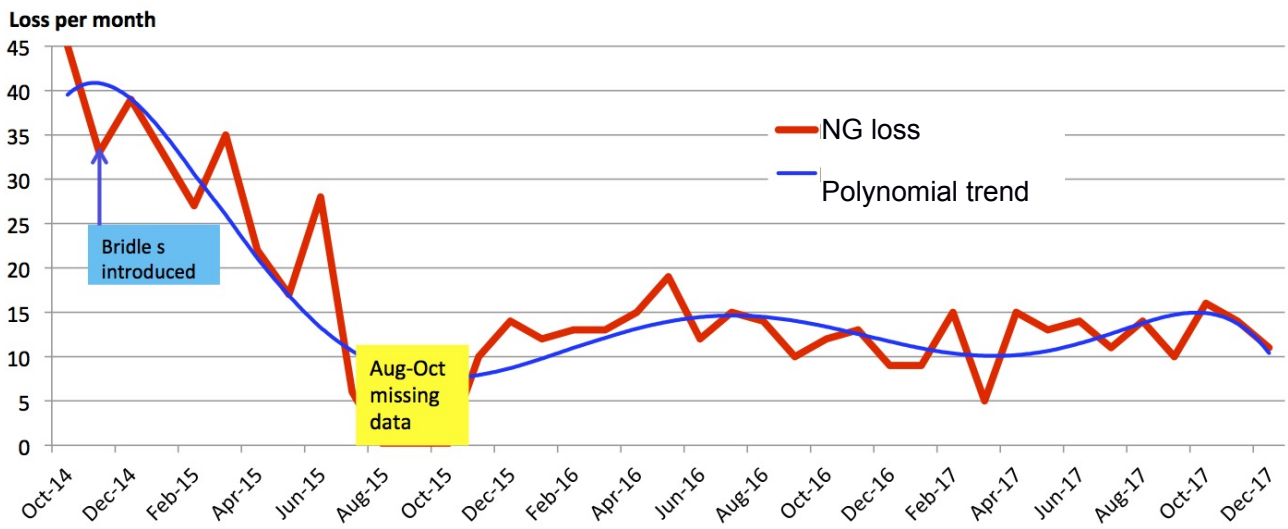
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### 110 **NG tube loss**

111 During October 2014, 45 NG tubes were lost. From 01.11.014 nasal bridles began to be fitted to NG tubes  
 112 but the policy only became established over several months as staff trained in bridle use. Although NG tube  
 113 and bridle use were not audited, compared with October 2014, one year from 'bridle introduction' NG tube  
 114 loss (Figure 1) or tube loss per ICU admission or per ventilated days fell by more than 50%, using data from  
 115 648 tube losses.

116

Figure 1: NG tube loss per month.



119 **NI tube loss**

120 Reasons for tube loss was documented in all 710 NI tube placements from 01.1.10 to 31.12.17. Unbridled  
 121 versus bridled patients were similar in age, APACHE 2 score, height, weight, sex and the proportion sedated  
 122 or unconscious (Table 1.1). However, in the new ICU it became practice to place a tracheostomy later so a  
 123 higher proportion of bridled patients retained an endotracheal tube, patient mix included more non-trauma  
 124 neurosurgical and fewer trauma patients and NI tubes were placed earlier during ICU admission.

Table 1 Patient demography and clinical state.

Parameter	No Bridle		Bridle		P value
	Median	IQR	Median	IQR	
Age	55.4	38.3-69.2	53.6	37.6-69.5	0.75
APACHE 2 score	15	8-22	15	10-20.5	0.76
Height	174	166-180	175	166-180	0.38
Weight	77.4	68-88	80	70-90	0.15
	<b>N</b>	<b>%</b>	<b>N</b>	<b>%</b>	
Sex (male)	211	72.5	160	69.3	0.44
Disease category					< 0.0001
Medical	86	29.6	47	20.3	
Neurosurgical (non-trauma)	21	7.2	46	19.9	
Surgery (non-neurosurgery)	75	25.8	69	29.9	
Trauma	109	37.5	69	29.9	
Consciousness					0.82
Awake	47	22	48	21	
Sedated or unconscious	167	78	181	79	
Artificial airway					< 0.0001
None	43	15.5	27	11.8	
Endotracheal	153	55	176	76.9	
Tracheostomy	82	29.5	26	11.4	

125

126

127 From 2010-2014, 67-77 tubes were placed per year except for 2013 when only 47 were placed; 25 patients  
 128 were randomised to a prokinetic drug study instead of NI feeding. Following the combining of two hospitals  
 129 and preferential use of NI feeding over erythromycin when metoclopramide fails, annual NI tube use rose to  
 130 between 95-101.

131

132 The predominant reason for NI tube loss, prior to bridle use was inadvertent patient removal or slippage. On  
 Figure 2: Cause of inadvertent NI tube loss.

133 an open ICU, 2010-2013, this occurred in  $\epsilon$  %

134 before, during and after ICU patients were

135 approximately 9% once all NI tubes were bridled

136 risk reduction (OR: 0.2, 95%CI: 0.12-0.33,  $p <$

137 risk of loss. Apart from tubes being lost to block

138 losses (spontaneous or endoscopic displacement)

139 term feeding routes, clinical procedures or vor

140

141 Reduced tube loss was paralleled by an index

142 0.7-3.7,  $p = 0.004$ ); age was negative

143 nearly 3-fold increase in **planned** tra

144 0.0001) (weight, male gender negativ

145 redundant at its removal (OR: 2.3, 95

146 and male gender were positively and n

147

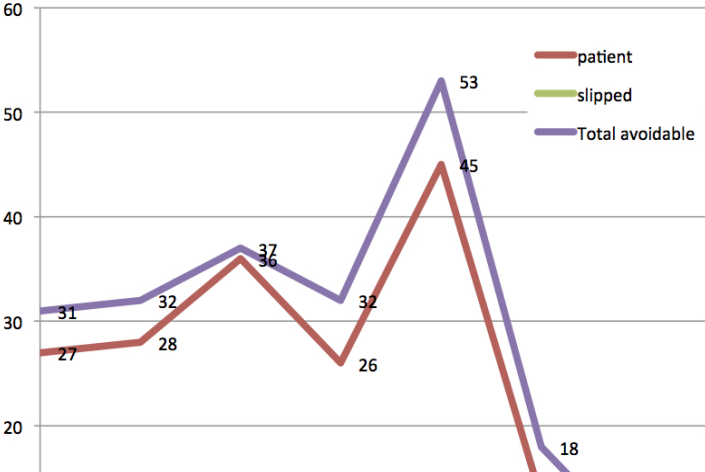


Figure 3: Reason for NI tube removal due to redundancy.

142 0.7-3.7,  $p = 0.004$ ); age was negative

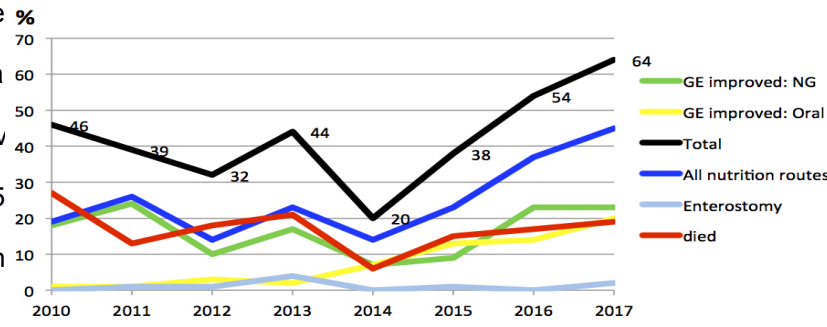
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148 **Effect on potential risk**

Table 2 represents the potential current complication rates associated with 'blind', that is unguided, NG and NI tube placement. This assumes 90% of UK-purchased tubes are placed, current misplacement rates and estimates the risk reduction if bridle securement, as in the current study, achieved a 40% reduction in premature tube loss and replacement.

Table 2 UK tube use, complication rates and potential effect of bridles.

Tube use and complications	N or %	Tape	Bridle
		90% placed*	40% reduction
Tubes per y UK	790000	711000	284400
<b>Complication rate**:</b>	%		
■ Lung	1.5	10665	4266
■ Pneumothorax,	0.5	3555	1422



pneumonia			
■ Death	0.27	1920	768
■ Oesophageal: placement	20	***142200	56880
undetected**		35550	14220

149 \*90% of UK purchased tubes are placed to a length approximating the gastric or lung positions.

\*\* Summarised from [Taylor. 2018 from Sorokin and Gottlieb. 2006; Kooperman et al. 2011; Krenitsky. 2011; Rayner. 2013; Rollins et al. 2012].

\*\*\* Assumption: 50% detected by X-ray; 50% of the remainder (25%) detected by pH  $\leq$ 5.5.

150

## 151 Discussion

### 152 *Primary findings*

153 Most NG and NI tubes secured with tape are lost before they are no longer required. For NI tubes  
154 approximately 35% were lost to inadvertent patient removal and slippage on an open ICU ward. This  
155 increased to 53% when combining two ICUs and nursing patients in single rooms, then fell to 9% after bridle  
156 securement. Bridle securement was independently associated with this reduction in inadvertent tube loss.  
157 Bridle securement was associated with a more gradual increase in the proportion of patients progressing to  
158 alternative feeding routes; it is unclear why this lagged behind the decline in tube loss.

159

### 160 *Inadvertent tube loss*

161 Inadvertent tube removal or slippage occurs in up to 73% of tubes when using tape securement [Brazier et  
162 al. 2017]. Patients with neurological disease appear most prone to patient removal [Taylor et al. 2015],  
163 occurring in 82% of stroke patients [Brazier et al. 2017]. In a hospital-wide population although risk of patient  
164 tube removal increases with each removal (0: 61%, 1: 66%, 2: 70%) it was not confined to specific patient  
165 groups [Taylor et al. 2015]. And, the rapidity of changes in sedation, level of consciousness and tape  
166 adherence make patient tube removal or slippage unpredictable.

167

168 In contrast, because about 6% of hospitalised patients require NG or NI feeding [Elia. 2015] the need for 30-  
169 50% of tubes to require replacement represents a significant healthcare risk and cost [Taylor et al. 2014a].  
170 National alerts and extra radiological training have failed to prevent undetected misplacements [NHSI. 2016].  
171 Many patients require several tube replacements ( $\geq 3$ : 28-59% [Brazier et al. 2017; Taylor et al. 2015] and  
172 misplacement risk increases from an average of 2.1% to 32% when there has been previous misplacement  
173 and risk of pneumothorax increases from 5% after the first misplacement to 36% after  $\geq 3$  [Marderstein et al.  
174 2004].

175

### 176 *Implications for safety*

177 pH or X-ray confirmation do not prevent tube misplacement which represents more than 90% of the burden  
178 of misplacement morbidity and mortality [NPSA. 2011; NHSI. 2016] (Table 2). The number of complications  
179 from undetected oesophageal misplacements is unknown. Because most misplacements are detected and  
180 the tube correctly repositioned, clinicians often fail to realise that misplacement was the cause of  
181 complications. The reduction in complications when nasal bridles are placed pre-emptively is based on the

182 reduction in inadvertent patient removal and slippage in this study, in single patient rooms, obviating the  
183 need for tube replacement.

184

185 Actual placements, and thus misplacements and complications, will depend upon the patient population.  
186 Patients with impaired neurology, including critically ill and stroke patients, are prone to inadvertent tube loss  
187 but also form a large proportion of tube fed populations [Taylor et al. 2014a; 2015; Brazier et al. 2017]. If the  
188 UK tube-fed population were similar to our ICU NI tube-fed patients, pre-emptive bridle placement is  
189 predicted to prevent 1422 major complications and 768 deaths. Bridle securement could also reduce delays  
190 to feed and drug delivery [Segaran et al. 2015; Brazier et al. 2017] thereby improving clinical outcome and  
191 reducing healthcare staff burden.

## 192 Cautions

193 This study was observational so un-measured confounders may partly explain findings. For example, after  
194 introducing nasal bridles, there was a progressive, rather than single-step, reduction in tube loss and  
195 increase in patients no longer needing their tube prior to 'loss'. However, improved training in positioning of  
196 the bridle clip could explain the decremental reduction in tube loss after introduction of bridles. Equally,  
197 increased retention of tubes until redundant might lag behind reduction in tube loss, because only once tubes  
198 are secured would there be an imperative to improve tube maintenance, such as flushing. Lastly, the effects  
199 of bridle introduction were large after accounting for most potential confounders.

200

## 201 Conclusions

202 On moving from tape to bridle securement, inadvertent tube loss fell from 53% to 9% while the number of  
203 patient's tube's that reached redundancy increased from 20% to 64%. While this study is retrospective and  
204 single-centre the independent associations appear very strong. A similar effect UK-wide should achieve  
205 major reductions in misplacement-associated complications and death. Further investigation, including  
206 randomised controlled trials, is required to determine whether these changes affect hospital length of stay  
207 and holistic treatment cost.

208

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211

## 212 Appendix Regression models including bridle securement adjusted for potential confounding factors.

Model	Independent variable	* 95% CI	P value
Inadvertent tube loss		<b>OR 2.5% 97.5%</b>	
	(Intercept)	0.51 0.21 1.15	0.11
	<b>bridle</b>	<b>0.20 0.12 0.33</b>	<b>&lt; 0.0001</b>
	disease_neurosurgical (non-trauma)	1.60 0.68 3.68	0.27
	disease_surgery (general)	1.03 0.50 2.12	0.93
	<b>disease_trauma</b>	<b>2.57 1.42 4.76</b>	<b>0.002</b>
	sedated_unconsciousness (vs awake)	1.53 0.69 3.55	0.31
	airway_endotracheal	0.58 0.22 1.49	0.26
airway_tracheostomy	0.71 0.27 1.82	0.48	
Tube duration of use		<b>Days 2.5% 97.5%</b>	
	<b>(Intercept)</b>	<b>9.63 6.19 13.06</b>	<b>&lt; 0.0001</b>
	bridle	2.21 0.70 3.72	<b>0.004</b>
	age	-0.06 -0.09 -0.02	<b>0.005</b>
kg	0.03 -0.01 0.06	0.13	
Planned transfer to alternative nutrition		<b>OR 2.5% 97.5%</b>	
	(Intercept)	0.41 0.15 1.10	0.08
	<b>bridle</b>	<b>2.83 1.86 4.34</b>	<b>&lt; 0.0001</b>
	<b>APACHE 2 score</b>	<b>0.94 0.91 0.97</b>	<b>&lt; 0.0001</b>
	age	1.00 0.99 1.01	0.90
	sex	0.58 0.36 0.94	0.03
	kg	1.01 1.00 1.02	0.13
Tube no longer needed		<b>OR 2.5% 97.5%</b>	
	(Intercept)	0.48 0.25 0.91	0.03
	<b>bridle</b>	<b>2.26 1.55 3.31</b>	<b>&lt; 0.0001</b>
	<b>sex</b>	<b>0.55 0.36 0.82</b>	<b>0.004</b>
	<b>airway_endotracheal</b>	<b>2.04 1.15 3.73</b>	<b>0.017</b>
	<b>airway_tracheostomy</b>	<b>2.24 1.14 4.51</b>	<b>0.021</b>
	NJ tube_ICU day of placement	0.98 0.94 1.00	0.165

\*95% confidence interval of OR or estimate.