Identifying patients at increased risk of non-ventilator associated pneumonia on admission to hospital: a pragmatic prognostic screening tool to trigger preventative action.

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Abstract

Background: Non-ventilator healthcare associated pneumonia (NV-HAP) is an important healthcare-associated infection. This study tested the feasibility of using routine admission data to identify those patients at high risk of NV-HAP who could benefit from targeted, preventive interventions.

Methods: Patients 64yrs or older, who developed NV-HAP five days or more after admission to elderly care wards, were identified by retrospective case note review together with matched controls. Data on potential predictors of NV-HAP was captured from admission records. Multivariate analysis was used to build a prognostic screening tool (PRHAPs); acceptability and feasibility of the tool was evaluated.

Results: A total of 382 cases/381 control patients were included in the analysis. Ten predictors were included in the final model; nine increased the risk of NV-HAP (OR between 1.68 and 2.42) and one (independent mobility) was protective (OR 0.48; 95% CI 0.30-0.75). The model correctly predicted 68% of the patients with and without NV-HAP; sensitivity 77%; specificity 61%. The PRHAPs tool risk score was 60% or more if two predictors were present and over 70% if three were present. An expert consensus group supported incorporating the PRHAPs tool into electronic logic systems as an efficient mechanism to identify patients at risk of NV-HAP and target preventative strategies.

Conclusions: This prognostic screening (PRHAPs) tool applied to data routinely collected when a patient is admitted to hospital, could enable staff to identify patients at greatest risk of NV-HAP, target scarce resources in implementing a prevention care bundle, and reduce the use of antimicrobial agents.

Background

Healthcare associated pneumonia (HAP) is the most common healthcare-associated infection (HCAI) identified in point prevalence surveys, accounting for approximately 23% of HCAI with the greatest risk in elderly patients.[1,2]). HAP was considered to be predominantly associated with devices that compromise the innate immune defences of the airway e.g. mechanical ventilation with prevention efforts targeted at these device-associated infections.[3] However, only a quarter of HAP are associated with devices and there is a deficit in activity targeted at preventing non-ventilator associated HAP (NV-HAP).[1,3,4,5]

NV-HAP is an important cause of serious illness and has a greater risk of mortality than community acquired pneumonia (CAP).[6] It is a major driver of antimicrobial prescribing, accounting for a quarter of therapeutic antimicrobial prescriptions and presents significant challenges for antimicrobial stewardship.[7,8] Strategies that target interventions to prevent HAP at patients most at risk could help drive reductions in antimicrobial use.

The aetiology of NV-HAP is linked to aspiration of oropharyngeal secretions into the intrathoracic airway.[9] Risk factors which increase the risk of NV-HAP include conditions or medications that impair swallowing, mobility or alertness or alter oropharyngeal flora.[10-16] A number of interventions to prevent NV-HAP have been proposed but the capacity of staff to implement them may be limited in the context of highly-dependent patient caseloads.[17,18] Targeting prevention at those patients at greatest risk of NV-HAP may be the most feasible approach but requires a tool to identify them at the time of admission so that appropriate preventative measures can be implemented. For such a tool to be practical and effective it should not increase the burden of assessment for clinical staff. This study aimed to test the feasibility of using data routinely captured in the nursing admission assessment and case notes to identify those patients at high risk of developing NV-HAP who may benefit most from targeted, evidence-based preventive interventions.

Methods

The study was designed in two phases.

Phase One: Developing the Predictive Model and PRHAP Tool

A retrospective case note review was conducted in two large university teaching hospitals in England between October 2021 and May 2022. Data were captured on potential predictors of NV-HAP in patients 64 years or more admitted for acute care to elderly medicine or trauma and orthopaedics and with a hospital stay of at least five days between 2017 and 2020. Potential predictors were selected which met the following criteria: (1) evidence from the scientific literature of an association with NV-HAP and (2) routinely recorded in the nursing/medical admission records (Table I). Multivariate analysis was used to identify significant independent predictors of NV-HAP and build a prognostic screening tool.

The sample size estimates were conducted with G*Power using immobility as the primary predictor of NV-HAP because this variable was likely to be recorded in admission records and had been associated with a 2.8 increased risk of NV-HAP.[12] The sample size estimation model assumed an NV-HAP incidence of 6%, 50% of patients as immobile[2,12] , 80% power to detect a significant (at the 0.05 level) difference in the incidence of pneumonia between the mobile (incidence estimated at 3.4%) and immobile (incidence estimated at 8.6%) populations, corresponding to an odds ratio of 2.5. The other predictor variables were predicted to have a moderate association with immobility (estimated R-square of 0.25). Using these parameters, a total sample size of 822 (411 cases and 411 controls) would be required to detect a significant model for a one-tailed hypothesis.

Definition of case and controls: Cases were identified by screening pharmacy records for standard prescribing protocols for first line treatment of patients with NV-HAP (Hospital A - ceftazidime) or clinical coding for antimicrobial treatment for HAP (Hospital B - e.g. Tazocin, Co-amoxiclav, doxycycline, levofloxacin) and confirmed as meeting the case definition of NV-HAP by a consultant clinical microbiologist. Cases of NV-HAP were defined as patients with a date of onset of symptoms of pneumonia five days or more after their date of admission to hospital with signs and symptoms meeting the case definitions (Web appendix 1).

Controls were patients without NV-HAP selected at random from among other patients of 64 years or older admitted within 4 weeks to the same set of wards as a case (patient with NV-HAP). Patients with CAP or mechanical ventilation during this admission; transferred from another hospital with pneumonia were excluded from the control group (Figure 1). Data were extracted from the clinical records by an infection prevention and control practitioner at each site.

Data Analysis: The analysis was informed by the PROGRESS framework for statistical prognostics models[19] and based on recommendations of Traeger *et al.*[20] An exploratory univariate analysis used the chi-squared test to identify predictors significantly associated with being a case (prognostic variable). Dichotomous variables were created for BMI (obese vs. other) and smoking status (yes vs. no); mobility descriptors were categorised as 'dependent' (bed or chair bound or immobile), 'independent' (fully mobile or no assistance) and 'requires assistance' (any other descriptor). Age and rank TDI were included in the model as continuous variables. Categorical predictor variables were included in the regression model if less than 8% of the data was missing; the size of effects associated with the predictor was >0.1 (Phi coefficient) and there were more than 10 cases per predictor variable.

The model was developed using automated backward selection and Likelihood-Ratio statistics. All predictor variables were included at the beginning, with the weakest contributors removed until a removal significantly affected the fit of the model with the significance level set at $p<0.10$. A NV-HAP risk score was generated for each case by calculating the sum of the products of the values of each predictor variable and its regression coefficient and multiplying each by 1 or 0 depending on whether the condition was present or not.

The ability of the model to discriminate between patients with (case) or without (control) NV-HAP was evaluated using a Receiver Operator Characteristic Curve (ROC) analysis over the risk index. The predicted probability of NV-HAP from the regression model was used as the test variable and the actual outcome of NV-HAP as the state variable. The accuracy of the model (area under the curve (AUC) statistic) and probability of true positives (sensitivity) and true negatives (specificity) for a given pair of test and state values was determined. An AUC statistic of 0.7–0.8 acceptable discrimination.[20]

Phase Two: Determining Acceptability and Feasibility of the PRHAPs tool

An online national survey was developed to identify what data NHS Trusts collect to monitor cases of NV-HAP; tools used to identify patients at increased risk of NV-HAP and prevention of NV-HAP programmes. The survey was created in Qualtrics™ software for electronic completion (Web Appendix 2) and publicised via professional networks including the Infection Prevention Society**.** Consent to participate was implied through completion of the survey. Descriptive statistics were used to summarise the data using Statistical Package for the Social Sciences software version 27 (SPSSv27).

A multidisciplinary Expert Consensus Group was drawn from IPC experts across the UK and participants in the online survey. The consensus event was held online via MS Teams. They were asked to consider the value of the risk index tool for identifying patients at high risk of NV-HAP; patient groups it should be applied to; which prevention strategies are practical to apply; and how the risk index tool could be applied in practice? Potential prevention strategies were identified from current literature.[21,17] Responses were captured through the discussion which was recorded and the polling function on MS Teams.

Ethical Approval: Ethical approval was received from Health Research Authority and Health and Care Research Wales REC reference 19/LO/1978; IRAS Project ID 271138. The project also received University ethics approval: UWL CNMH Ethical Approval No. 00724. Permission to capture data from patient records was sought from the Caldicott Guardian. No patient identifiers were retained.

Results

Risk factors for NV-HAP

A total of 763 patients (382 NV-HAP cases and 381 control patients without NV-HAP) were included. Disruption caused by the SARS-CoV-2 pandemic limited the number of patients available for inclusion in the study and data collection ceased before the target number of 411 cases in each group could be reached. The mean age for all included patients was 83 with a minimum age of 64 and maximum age of 106. The frequency distribution of the categorial predictor variables together with the univariate analysis of the association of each predictor variable with NV-HAP are shown in Table II.

Fourteen categorical predictors, age and TDI were included in the logistic regression model. The backward selection procedure terminated in five steps with the removal of the following variables dysphagia, age, gender and Townsend Deprivation Index Rank. The final model included ten predictor variables (Table III). Nine of these predictors were identified as risk factors increasing the odds of NV-HAP with odds ratios (OR) between 1.68 to 2.42, and one (independent mobility) protective factor decreasing the odds of NV-HAP by 52% (OR 0.48; 95% CI 0.30-0.75) compared to requires assistance and by 300% compared to dependant patients. Cognitive impairment, use of benzodiazepines and chronic respiratory disease all more than doubled the odds of NV-HAP. The model improved the detection of true positives (sensitivity) from chance (50%) to at least 77%; whilst the detection of true negatives

(specificity) was slightly less at 61%. Overall correct predictions using this model occurred for 68.5% of all individuals (Table IV).

The prognostic tool

A risk index score was calculated for each patient (equation in web appendix 3). This calculator forms the prognostic screening tool or PRHAPs tool and an example is shown in Table V. None of the predictors generated a score of more than 50% on their own (although cognitive impairment and benzodiazepines both scored 50%). However, if two predictors were present, most combinations generated a score of more than 60% and if three were present most combinations generated a score of more than 70%. Dependant mobility only scored 44% alone but commonly occurred in combination with other risk factors. Mobility was an important determinant factor and would reduce the predicted risk of NV-HAP by approximately 20%. For example, a patient admitted with dependent mobility, cognitive impairment, an oral management plan (indicating that the patient was recognised to have swallowing difficulties) and on benzodiazepines had a predicted probability of developing NV-HAP of 89.76%, but if the same patient had independent mobility their probability of develop NV-HAP would reduce to 67.9%.

The three most common risk factors identified among cases were dependent mobility found in 38.6% (145/382), an oral management plan in 34.4% (131/382) and chronic respiratory disease in 29.6% (113/382). Of the 137 patients with cognitive impairment, 27 (20%) were also on benzodiazepines of which 23 (85%) were cases, and 12 (all cases) were categorised as dependent mobility. In the case patients, 29.3% had only one risk factor and a further 28% had two risk factors. Patients with between one and three risk factors accounted for 75% of the cases and none of the cases had more than five risk factors. None of the nine risk factors were present in 10% of cases (Web Appendix 4).

The ability of the PRHAPs tool to discriminate between patients who developed (case) or not (control) NV-HAP was found to be acceptable (AUC = 75%).

Practicality and feasibility of the PHRHAP tool

Sixteen participants from different clinical specialisms and NHS trusts in England and Wales attended the multidisciplinary expert consensus meeting. All participants agreed that the PRHAPs tool would be useful in supporting the prevention of NV-HAP. Eleven participants would use it with an NV-HAP prevention bundle for patients admitted with at least one risk factor (68%, n=11/16), and three participants would focus prevention on individual risk factors.

Incorporating the PRHAPS tool into an electronic logic system which would automatically identify patients at risk was considered the most effective approach as it was important the tool did not increase the workload of clinical staff as staff can be overwhelmed by the number of alerts flagged in patients' records. The four key preventative actions to be included in an NV-HAP prevention bundle were oral hygiene (100%, n=16/16), increasing mobilisation (94%, n=15/16), swallowing evaluations to promote safe feeding (94%, n=15/16) and a reduction in the use of sedatives and PPI (75%, n=12/16). The majority considered the tool should be applied to all admissions (70%, n=11/16) rather than admissions to specific wards (12%, n=2/16) or only patients over age 65 (18%, n=3/16). It was suggested patients, or their relatives could assist in carrying out some of the prevention strategies e.g. oral hygiene, tooth brushing and facilitated by the education team. A mechanism of monitoring the use of the tool was suggested to ensure recommended actions were implemented.

Survey of current activity focused on NV-HAP prevention

A total of 30 responses were received. Only five respondents reported collecting data to monitor case/rates of NV-HAP and none reported using a standardized tool to identify patients at risk of NV-HAP. Programs focused on preventing NV-HAP were reported by 67% (20/30) for oral hygiene or mouthcare protocols, 70% (21/30) supporting/improving mobility and 53% (16/30) influenza vaccination.

Discussion

This study has developed a prognostic screening (PRHAPs) tool derived from routinely collected hospital admission data. It combines 10 independent predictors of NV-HAP, which together correctly predicted 68% of the patients with and without NV-HAP. If applied as an algorithm on admission, the tool could be used flexibly to identify patients at risk of NV-HAP and trigger action. For example, the trigger point could be set at a risk score of 60% or more which would equate to the presence of at least two risk factors. However, if the resources available to implement NV-HAP preventative actions were limited, then the threshold for action could be set at a higher level such as 80% or 90%. Independent mobility was a strong protective factor and if present would reduce the risk score even if other risk factors were present.

The risk factors identified in this analysis have also been reported by other recent studies.[18,22,23] The study by Chen *et al,*[22] also developed a model to predict NV-HAP risk, however although the C-index (0.813; 95%CI 0.77-0.85) and classification score (81%) was

slightly higher than ours, their model included complex measures such as the Charleston comorbidity index and Barthel Frailty Index which would make it difficult and time consuming to use as a routine approach to risk assessment. Similarly, a systematic review and meta-analysis found 24 factors were found to be associated with NV-HAP, some of which overlapped with the risk factors identified in our model but others would be difficult to incorporate into a simple risk assessment tool and therefore lack the practicality of our approach.[23] Stenlund *et al,*[24] in a retrospective analysis of medical records in patients admitted for acute abdomen or trauma, found a high risk of NV-HAP in immobile patients (OR 11.2) but a two-fold higher risk in patients with a suspected or verified aspiration event (OR 23.9). Although this confirms that an aspiration event is associated with NV-HAP, this information is not routinely recorded in admission records and would therefore not be suitable for inclusion in this pragmatic model.

Specific risk assessment tools to drive preventative action for patients identified as at risk of NV-HAP have been proposed.[25] However, healthcare staff are already asked to complete many different risk assessments and our stakeholders told us that any NV-HAP tool should not add to clinical staff workload. A key advantage of our prognostic screening tool is that rather than creating an additional burden of data collection it makes use of information that is already collected in other screening tools and the clinical history. Where electronic patient record systems are in use, the risk index score could be calculated automatically on admission from the data entered into the patient's electronic record.

If the predictors in the admission data generate a risk index score that is above a pre-determined threshold this should trigger action to reduce the risk of NV-HAP. Although evidence-based guidelines for the prevention of NV-HAP do not currently exist, there is some evidence to support some interventions. A systematic review and meta-analysis of randomized controlled trials of oral hygiene found that mechanical brushing after each meal in conjunction with professional dental care was effective in preventing pneumonia, although the three included studies were conducted in nursing homes rather than acute hospitals.[26] A quality improvement initiative, using an oral care implementation toolkit has shown that twice daily oral care significantly reduces the risk of developing NV-HAP.[27] Other studies on oral hygiene comprising mechanical brushing and/or oral disinfection reduced the risk of NV-HAP although the RCTs were generally of poor quality.[17,25,27-32] There is also some evidence that the removal of false teeth overnight reduces the risk of pneumonia.[33]

Dysfunction of the swallowing mechanisms increases the risk that microorganisms colonising the oropharynx are aspirated into the airway.[34] Strategies to enhance safe

swallowing such as maintaining an upright position during feeding, controlling portion size and food texture, encouraging swallowing, mouth clearance and appropriate pacing of mouthful can reduce the risk of aspiration.[35] A quality improvement initiative using a nurse-administered bedside screen with rapid bedside swallow evaluation demonstrated a decreased prevalence of pneumonia among patients with stroke.[36]

Several studies have focused on early mobility as a prevention strategy. A non-randomised clustered controlled trial undertaken by Stolbrink *et al*[12] demonstrated a significant reduction in the incidence of NV-HAP (hazard ratio of 0.39; 95% CI 0.22–0.68) associated with an early mobility bundle for patients who had undergone hip surgery. Another RCT evaluated the preventive effect of a "turn-mob" program for 223 bed bound patients with acute ischemic stroke. and was associated with a 61% decrease in incidence of HAP although the intervention was recognised as too resource intensive to be used as a routine prevention measure.[37]

The evidence base for the efficacy of medications reviews is poor, however, avoiding the use of other drugs that do increase the risk of NV-HAP such as antipsychotics and drugs that depress consciousness may be a feasible in some patients. Given that about 20% of cases of NV-HAP occur in the presence of viral infections, other strategies such as ensuring that influenza vaccinations are not missed by those in hospital is an additional pragmatic intervention.[17]

Our expert group recommended incorporating preventative actions into a bundle comprising these four measures, to be applied to all patients identified as at risk, rather than bespoke action to address specific risk factors in individual patients. They also proposed patients and their families could be involved in implementation of the care bundle, e.g. by supporting oral hygiene, swallowing safety and mobilization, and the tool could also be used to trigger appropriate referrals to the wider multidisciplinary team e.g. SALT and physiotherapy.

An observational study by Lacerna *et al*[21] reported a reduction in rate of NV-HAP from 5.92 to 1.79 per 1,000 admissions associated with the introduction of a prevention bundle. However, despite the major burden of morbidity, mortality and antimicrobial consumption associated with NV-HAP, our survey suggested that few NHS acute Trusts have a formal approach to identifying patients at risk of the infection or implementing prevention activity. Evidence also suggests that fundamental elements of nursing care associated with prevention of HAP are often neglected.[38] Using this prognostic screening tool in the routine

admission record in combination with a NV-HAP prevention bundle presents a pragmatic approach to targeting limited care resources at those patients at greatest risk.

Study limitations

Our study has several limitations. Disruption caused by the SARS-CoV-2 pandemic meant that we could not include the target sample of cases and controls in the model. However, the model was still able to provide adequate discrimination between cases and controls. The model identified the risk of NV-HAP correctly in two thirds (68%) of cases and therefore would miss some patients at risk of NV-HAP. However, this would seem acceptable given that the prognostic screening tool aims to provide a pragmatic and resource-light method of identifying patients at greatest risk of NV-HAP to target scarce resources for prevention activity. Clearly there are likely to be other risk factors for NV-HAP that are not readily available in admission data, however, we consider that we were able to collect the most important factors. We did not exclude patients in either group who received antibiotics for other reasons, but it seems unlikely that this would have affected the groups differently.

Missing nutrition data meant we were unable to include the presence of a feeding tube, dentures, and weight loss in the regression model. However, the difficulty in collecting this data only occurred at one site and the other site had less than 5% missing data for these variables. This suggests that whilst this affected our ability to include these variables in this analysis the collection of this data for a future prognostic tool is feasible. Additionally, BMI was not included in the model due to missing data, however, other studies have not found an association.[18,22,23] The prognostic screening tool was based on a small case control study and would benefit from being validated in a prospective study in combination with a prevention bundle to determine its efficacy in reducing the incidence of NV-HAP.

The response rate for survey was disappointingly low but not necessarily unusual for this type of instrument. Whist we attempted to have patient participation in the expert workshop this was not possible and in future we would aim to also involve other professional groups in the MDT.

In conclusion, this prognostic screening (PRHAPs) tool applied to data routinely collected when a patient is admitted to hospital, could provide practical means of enabling staff to identify patients at greatest risk of and target scarce resources in implementing an NV-HAP prevention care bundle. Preventing NV-HAP will also have an important impact on antibiotic usage and contribute to reducing antimicrobial resistance.

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Table I: Potential Predictors of NV-HAP Defined Data Set

Potential Predictor	Data set	Source of data
Demographics	Age, Gender, Deprivation	Nursing admission record Townsend Deprivation Index derived from post code
Nutritional Status	BMI, Weight Loss (last 6 months), Feeding Tube, Dentures, SALT Oral Management Plan	Nursing admission record Nutrition assessment
Lifestyle	Smoking Status	Nursing admission record Medical admission history
Mobility Status	Independent, Requires Assistance, Fully Dependent	Nursing admission record Mobility & falls risk assessment Pressure ulcer assessment
High Risk Medications	Benzodiazepines, Neuroleptics, Anti-Depressants (tricyclics, mirtazapine, venlafaxine, trazadone), Antihistamines, Antiepileptics, Parkinson's disease (Sinemet, Madopar)	Medical admission history
High Risk Underlying Conditions	Diabetes, Dementia, Cognitive Impairment, Dysphagia, Stroke, Chronic Respiratory Disease, Heart Failure	Medical admission history
Recent High-Risk Events in the Last 4 Weeks	Previous Admission, Pneumonia, Surgery, SALT referral	Medical admission history

Table II: Univariate analysis of the association of each predictor variable with NV-HAP

	Predictor	Category	Case (n=382)	Control (n=381)	Total (n=763)	Missing Data	P-value	Phi	In regression
Nutrition & Lifestyle	Age					0 (0%)	.894	-.005	Yes
	Gender	Yes	195 (51%)	202 (53%)	397 (52%)	0 (0%)	.586	.02	Yes
		No	187 (49%)	179 (47%)	366 (48%)				
	TDI Rank	Yes	185 (48.9%)	163 (43%)	348 (46%)	6 (1%)	**.015**	-.072	Yes
		No	193 (51.1%)	216 (57%)	409 (54%)				
	BMI	Yes	39 (11.7%)	70 (20.4%)	109 (16.1%)	86 (11%)	**.002**	-.119	No
		No	295 (88.3%)	273 (79.6%)	568 (83.9%)				
	Weight Loss	Yes	6 (3%)	9 (4.4%)	15 (3.7%)	360 (47%)	.483	-.035	No
		No	191 (97%)	197 (95.6%)	388 (96.3%)				
	Feeding Tube	Yes	18 (9.1%)	4 (1.9%)	22 (5.5%)	360 (47%)	**.001**	.158	No
		No	179 (90.9%)	202 (98.1%)	381 (94.5%)				
	Dentures	Yes	10 (5.1%)	11 (5.6%)	21 (5.3%)	370 (48%)	.851	-.010	No
		No	185 (94.9%)	187 (94.4%)	272 (94.7%)				
	Oral Management Plan	Yes	131 (34.4%)	68 (17.9%)	199 (26.1%)	2 (0%)	**<.001**	.186	Yes
		No	251 (66.7%)	311 (82.1%)	562 (73.9%)				
	Smoker	Yes	70 (18.5%)	42 (12.9%)	112 (15.9%)	54 (8%)	.042	.077	No
		No	308 (81.5%)	284 (87.1%)	592 (84.1%)				
	Dependent Mobility	Yes	145 (38.6%)	67 (18.2%)	212 (28.5%)	19 (2%)	**<.001**	.225	Yes
		No	231 (61.4%)	301 (81.8%)	532 (71.5%)				
	Independent Mobility	Yes	37 (9.8%)	98 (26.6%)	135 (18.1%)	19 (2%)	**<.001**	-.218	Yes
		No	339 (90.2%)	270 (73.4%)	609 (81.9%)				
High Risk Medications	Benzodiazepines	Yes	82 (21.5%)	27 (7.1%)	109 (14.3%)	0 (0%)	**<.001**	.205	Yes
		No	300 (78.5%)	354 (92.9%)	654 (85.7%)				
	Neuroleptics	Yes	36 (9.4%)	16 (4.2%)	52 (6.8%)	0 (0%)	**.004**	.104	Yes
		No	346 (90.6%)	365 (95.8%)	711 (93.2%)				
	Anti-depressants	Yes	113 (29.6%)	97 (25.5%)	210 (27.5%)	0 (0%)	.202	.046	No
		No	269 (70.4%)	284 (74.5%)	553 (72.5%)				
	Antihistamines	Yes	53 (13.9%)	39 (10.2%)	92 (12.1%)	0 (0%)	.123	.056	No
		No	329 (86.1%)	342 (89.8%)	671 (87.9%)				
	Anti-epileptics	Yes	56 (14.7%)	25 (6.6%)	81 (10.6%)	0 (0%)	**<.001**	.131	Yes
		No	326 (85.3%)	356 (93.4%)	682 (89.4%)				
	Parkinson’s treatment	Yes	15 (3.9%)	13 (3.4%)	28 (3.7%)	0 (0%)	.705	.014	No
		No	367 (96.1%)	368 (96.6)	735 (96.3%)				

High Risk Conditions	Diabetes	Yes	92 (24.1%)	94 (24.7%)	186 (24.4%)	1 (0%)	.834	-.008	No
		No	290 (75.9%)	286 (75.3%)	576 (75.6%)				
	Dementia	Yes	100 (26.2%)	71 (18.6%)	171 (22.4%)	0 (0%)	.012	.090	No
		No	282 (73.8%)	310 (81.4%)	592 (77.6%)				
	Cognitive impairment	Yes	97 (25.4%)	40 (10.5%)	137 (18%)	0 (0%)	**<.001**	.194	Yes
		No	285 (74.6%)	341 (89.5%)	626 (82%)				
	Dysphagia	Yes	64 (16.8%)	30 (7.9%)	94 (12.3%)	1 (0%)	**<.001**	.136	Yes
		No	317 (83.2%)	351 (92.1%)	668 (87.7%)				
	Stroke	Yes	63 (15.5%)	43 (11.3%)	106 (13.9%)	0 (0%)	.038	.075	No
		No	319 (83.5%)	338 (88.7%)	657 (86.1%)				
	Chronic Respiratory Disease	Yes	113 (29.6%)	55 (14.4%)	168 (22%)	0 (0%)	**<.001**	.183	Yes
		No	269 (70.4%)	326 (85.6%)	595 (78%)				
	Heart Failure	Yes	90 (23.6%)	53 (13.9%)	143 (18.7%)	0 (0%)	**<.001**	.124	Yes
		No	292 (76.4%)	328 (86.1%)	620 (81.3%)				
High Risk Events	Admission in last 4 weeks	Yes	45 (11.8%)	42 (11%)	87 (11.4%)	1 (0%)	.733	.012	No
		No	336 (91.3%)	339 (89%)	675 (88.6%)				
	Pneumonia within 12 months	Yes	33 (8.7%)	11 (2.9%)	44 (5.8%)	1 (0%)	**<.001**	.124	Yes
		No	348 (91.3%)	370 (97.1%)	718 (94.2%)				
	Surgery in last 4 weeks	Yes	39 (10.2%)	33 (8.7%)	72 (9.4%)	1 (0%)	.457	.027	No
		No	342 (89.8%)	348 (91.3%)	690 (90.6%)				
	SALT[3] referral within 12 months	Yes	37 (9.7%)	23 (6%)	60 (7.9%)	0 (0%)	.061	.068	No
		No	345 (90.3%)	358 (94%)	703 (92.1%)				

Effect Sizes: 0.1 = small; 0.3 = medium 0.5= large
Spearman's Rho
Kendall's Tau

1. >5% last 5 months
2. Yes = current smoker

*not included in regression analysis as >8% missing data

Table III: Logistic regression coefficients predicting HAP using the backward procedure

Programme/ Activity	B	S.E.	Sig.	Odds ratio	95% CI for Odds Ratio	
Constant	-.89	.144	<.001	0.41		
Oral Management Plan	.62	.194	.001	1.87	1.28	2.73
Mobility Dependent	.68	.194	<.001	1.97	1.35	2.88
Mobility Independent	-.74	.234	.001	0.48	0.30	0.75
Intake of Benzodiazepines	.88	0.26	.001	2.40	1.44	4.00
Intake of Neuroleptics	.62	.357	.083	1.86	0.92	3.74
Intake of Epileptic Medication	.76	.279	.006	2.15	1.24	3.71
Cognitive Impairment	.88	.228	<.001	2.42	1.54	3.78
Chronic Respiratory Disease	.85	.207	<.001	2.34	1.56	3.51
Heart Failure	.52	.214	.016	1.68	1.10	2.55
Pneumonia treatment in last 12mth	.69	.399	.084	1.99	0.91	4.35

Notes. [a]Reference category: 'requires assistance'; Nagelkerke R Square = .25; B = regression coefficient

Table IV: Classification table from logistic regression predicting HAP

		Predicted		Percentage Correct
		Case	Control	
Observed	Control	279	85	76.6%
	Case	146	224	60.5%
Overall Percentage				68.5%

Table V: Example of the PRHAPs Risk Index tool

Risk factor	Present (1) or not present (0) Patient A	Patient B
Oral Management Plan	**1**	**1**
Mobility - fully dependant	**1**	0
Mobility - independent	0	**1**
Benzodiazepines	**1**	**1**
Neuroleptics	0	0
Epileptic Medication	0	0
Cognitive Impairment	**1**	**1**
Chronic Respiratory Disease	0	0
Heart Failure	0	0
Treated for Pneumonia during Last 12	0	0
Risk Index Score	**89.76%**	**67.90%**

Note: A predictor that is present is coded 1 and if not present is coded 0

Table VI: Frequency of nine predictors among cases

No. Risk Factors Present	Number of Cases (n=382)	
	Count	Percentage
Zero	39	10.2%
One	112	29.3%
Two	107	28.0%
Three	67	17.5%
Four	35	9.2%
Five	16	4.2%
Six	6	1.6%
Seven	0	-
Eight	0	-
Nine	0	-

Figure titles

Figure 1: The PRHAPs Study Algorithm for Selection of Cases