Monitoring Oral Colonization as a Risk for Pneumonia in Complex Continuing Care: Lessons Learned from a Pilot Study

Le Suivi de la Colonisation Buccale Comme Risque de Pneumonie Dans les Soins Continus Complexes : Les Leçons Apprises d'une Étude Pilote

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Abstract

Oral health has become a topic of increasing concern for speech-language pathologists given recent evidence implicating oral colonization with pathogenic bacteria as a precursor condition contributing to aspiration pneumonia risk. In this study, we conducted an observational study of oral colonization over the 3-month interval between successive dental hygiene appointments for 10 residents of complex continuing care facilities. Oral swabs were taken at 5 time-points per participant and sent to a lab for microbiological analysis, with semi-quantification of bacterial species. The analyses failed to show the predicted pattern of incrementally greater counts of pathogenic bacteria as time post dental hygiene service increased. Additionally, measures of oral dryness using a Modified Schirmer Test failed to show any particular relationship to swab results. We discuss our own learnings regarding the complexity of oral colonization arising from this pilot study.

Abrégé

Avec le temps, la santé buccale est devenue un sujet de préoccupation pour les orthophonistes étant donné les preuves récentes mettant en cause la colonisation buccale par des bactéries pathogéniques comme état précurseur contribuant au risque de pneumonie par aspiration. Dans la présente recherche, nous avons mené une étude observationnelle de la colonisation buccale sur l'intervalle de trois mois séparant des rendez-vous successifs d'hygiène buccale pour dix résidents d'institutions de soins continus complexes. Des échantillons de salive ont été prélevés à cinq moments différents pour chaque participant et envoyés à un laboratoire pour analyse microbiologique, avec semi-quantification des espèces bactériennes. Les analyses n'ont pas montré la progression attendue de bactéries pathogènes en fonction du temps écoulé après le service d'hygiène dentaire. De plus, des mesures de sécheresse buccale à l'aide d'un test *Schirmer* modifié n'ont pas montré de relation particulière avec les résultats des échantillons de salive. Nous discutons ce que nous avons appris concernant la complexité de la colonisation buccale découlant de cette étude pilote.

A growing body of literature supports the link between oral microflora and the importance of oral hygiene in limiting the risk of pneumonia development. Dramatic improvements in general dental health in the Western world during the latter half of the 20th century mean that people are increasingly reaching old age with intact dentition (Gooch, Eke & Malvitz, 2004). Although this trend is indicative of improvements in the delivery of dental services, it brings with it an imperative to promote proper oral care delivery to older adults and the disabled in order to limit the oral-health related risk of systemic diseases such as pneumonia. Individuals who are dependent on others for oral care, such as populations residing in long-term care (LTC) facilities, are recognized to be at a significant disadvantage with respect to the provision of adequate oral care (Chalmers, Levy, Buckwalter, Ettinger & Kambhu, 1996; Fiske & Lloyd, 1992; Frenkel, Harvey & Newcombe, 2000; Grap, Munro, Ashtiani & Bryant, 2003; Holmes, 1996; ; MacEntee, Thorne, & Kazanjian, 1999; Paterson, 2000; Preston, Punekar & Gosney, 2000; Wardh, Hallberg, Berggren, Andersson & Sorensen, 2000). Many individuals in LTC settings also have dysphagia (swallowing impairment) that places them at risk for aspiration (the inhalation of oropharyngeal secretions and other material into the larynx and down to the lower respiratory tract), with the subsequent risk of developing aspiration pneumonia (Marik, 2001; Pikus et al., 2003).

Pneumonia is the leading cause of acute care hospitalization and the primary cause of death in many diseases found amongst LTC residents (Muder, 1998). The reported incidence of pneumonia in LTC settings is approximately 1.2 per 1,000 patient days (Loeb, McGeer, McArthur, Walter & Simor, 1999; Muder, 1998; Nicolle, 2001). More specifically, aspiration pneumonia constitutes 15.5% of all Medicare pneumonia admissions in the United States (Baine, Yu & Summe, 2001). Bacterial pneumonia (as opposed to viral pneumonia) is directly precipitated by aspiration (Marik, 2001). Aspiration is a common feature of dysphagia, particularly in the elderly population (Feinberg, Knebl, Tully & Segall, 1990; Marik & Kaplan, 2003; Pikus et al., 2003). A recent study suggests that individuals with Parkinson's Disease or dementia, who are confirmed to aspirate thin liquids, have between a 7 and 15% risk for developing pneumonia over a 3 month interval, even with the use of techniques to limit their aspiration, such as thickened liquids or the use of a chin-down posture when drinking thin liquids (Robbins, 2008). However, seminal work by Langmore and colleagues (1998) has suggested that dysphagia, by itself, is not an adequate risk factor to lead to pneumonia pathogenesis in older adults. Rather, factors related to oral health and dependency for oral care emerged as strong predictors of pneumonia, together with factors related to frailty, mobility and medical complexity (Langmore et al., 1998). In particular, excessive colonization of the mouth and oral secretions with bacteria that are known to be respiratory pathogens emerges from the literature as a primary factor in the pathogenesis of pneumonia (Langmore, Skarupski, Park & Fries, 2002; Terpenning et al., 1993; Millns, Gosney, Jack, Martin & Wright, 2003).

The recognition that oral hygiene is a factor that impacts a patient's risk for developing aspiration pneumonia has attracted the attention of speech-language pathologists (S-LPs), who are the primary clinicians involved in managing dysphagia. In a recent qualitative study using focus groups to explore perspectives on oral care amongst different health-care professionals, Canadian S-LPs expressed concern that oral hygiene is easily neglected amongst nursing care responsibilities, and reported taking on advocacy roles and even some hands-on provision of oral care, motivated by the desire to limit the risk of pneumonia (Yoon & Steele, 2012). Evidence of such advocacy is seen in the fact that S-LPs were involved in development of best practice guidelines for nursing oral care practice, published by the Registered Nursing Association of Ontario (RNAO, 2008). These guidelines define oral hygiene as "the practice of keeping the mouth clean and healthy by brushing and flossing to prevent tooth decay and gum disease" (p.16) and further conclude that Level IV evidence supports the recommendation that "nurses provide, supervise, remind or cue oral care for clients at least twice daily, on a *routine* basis" (p. 32). In another example, a water protocol intervention study for patients with dysphagia at a Canadian rehabilitation hospital involved explicit consideration of and planning for oral care needs, including needs for assistance and suctioning (Carlaw, Finlayson, Beggs, Visser, Marcoux, Coney & Steele, 2012). Expected oral care for the rehabilitation hospital where that study was performed is described as being done "first thing in the morning, prior to oral intake, and at bedtime" with procedural instructions detailed as "swab mouth or rinse-and-spit… prior to any water intake".

Poor oral hygiene is reported to lead to the elevated presence of respiratory pathogens in oropharyngeal secretions (Limeback, 1988; Loesche & Lopatin, 1998; Marsh, 1999; Mojon & Bourbeau, 2003; Mojon, Budtz-Jorgensen, Michel & Limeback, 1997; Mombelli, 1998; Scannapieco, 1999). When these pathogens are aspirated, they can overburden host defense mechanisms and lead to infection (Marik, 2001). For this reason, the promotion of high quality oral care should be a priority strategy

for limiting the occurrence of bacterial pneumonia, particularly for individuals with an increased risk of aspiration secondary to dysphagia. Several recent Japanese studies have reported that the provision of frequent professional dental services is effective in reducing the incidence of pneumonia and colonization of oral secretions with respiratory pathogens in individuals in LTC settings (Abe, Ishihara & Okuda, 2001; Adachi, Ishihara, Abe, Okuda & Ishikawa, 2002; Yoneyama et al., 2002). However, the extent and frequency of oral care in these studies involved full dental cleanings by a dental hygienist or dentist as frequently as once per week. This level of oral care intervention is much higher than the levels currently recommended in the RNAO oral care best practice guidelines, which apply to Ontario LTC facilities (RNAO, 2008). Indeed, it is difficult to imagine how the level of oral care described in these Japanese studies could ever be provided in the context of current levels of funding for public dental care in Canada. Prior literature does not demonstrate whether the delivery of *routine* dental hygiene services and oral care impact oral colonization with pathogenic bacteria in residents in LTC settings.

The primary purpose of this pilot study was to conduct a prospective longitudinal investigation in order to describe and better understand patterns of oral microbial colonization over time, and specifically to document the presence and quantitative load of respiratory pathogens, aerobic gram negative bacteria and *Candida albicans* in oral swabs collected from residents in Canadian LTC institutions. The two Ontario facilities where the study was conducted were complex continuing care (CCC) hospitals, where *routine* oral care involved quarterly visits to the dental hygienist for detailed cleaning, paired either with self-care or nursing care between dental hygiene appointments. Individual patients would receive daily oral care guided by an individualized oral care plan developed in consultation with the dental hygienist at an assessment within 3 weeks of admission. By policy, the expected frequency of nursing oral care provision was at least twice daily, with the basic procedure defined as brushing teeth or cleaning dentures as outlined in a nursing textbook (Perry and Potter, 1997). Suction toothbrushes were made available as an option for patients with serious oral infections, serious dysphagia, or reduced level of consciousness.

To our knowledge, a longitudinal study of oral colonization related to *routine* oral care has not previously been conducted in the LTC population, and it remains unknown whether existing oral care regimens are sufficient for managing and limiting oral colonization with bacteria known to be associated with the pathogenesis of pneumonia. We were primarily interested in documenting the time course of oral colonization in the context of *routine* oral care, and decided to do this through the monitoring of bacterial levels in a series of oral swabs taken over the course of a 3 month interval spanning two successive dental hygiene visits for each participant. Our specific hypotheses were that oral colonization with the pathogens of interest:

(1) would be at their peak just prior to the delivery of professional dental hygiene services;

(2) would decline to a minimum at the first measurement following professional dental hygiene care; and

(3) would subsequently increase across measurements taken at successive intervals following the delivery of professional dental hygiene care.

Methods

Participants. A convenience sample of 11 participants was recruited from two CCC facilities in the Greater Metropolitan Toronto Area, Canada. After the initial recruitment and consent, one participant withdrew from the study because she was no longer interested in participating, leaving a total of 10 participants, who were each followed for a three-month period. The units on which these individuals resided served patients with primary diagnoses of stroke and acquired brain injury. There was no exclusion of participants on the basis of age, gender, or ethnicity. Individuals with significant cognitive impairment (defined as a Cognitive Performance Score > 3 from the Minimum Data Set) were excluded due to concerns about their ability to provide informed consent, the expectation that they would need to be repeatedly re-oriented and re-consented for each encounter involved in the study, as well as the risk that they might inadvertently bite and/or swallow the materials that were to be used during data collection. Table 1 summarizes demographic and etiological information about the participants. We did not specifically recruit or exclude individuals with documented diagnoses of confirmed dysphagia or aspiration because this was a pilot study. Although dysphagia is known to occur broadly in the LTC population, the majority of participants in this study were eating an oral diet of normal consistency (Table 1). Three participants may be presumed to have had some degree of dysphagia: participant 1 was receiving a diet including chopped foods and thickened liquids; participant 10 was receiving enteral feeding and no oral intake; and participant 9 was on a normal consistency

oral diet but had a prior history of enteral feeding. None of these individuals underwent assessment to determine the nature of new swallowing concerns during the course of the study.

Data Collection

Medical history/Chart reviews. Retrospective chart reviews were conducted for each participant in order to record health status factors that might influence the results and interpretation of the oral colonization data. These factors are summarized in Table 1. Major medical diagnosis and comorbidities were documented as well as current route of feeding and diet consistency. The level of dependency for oral care was recorded, based on the dental hygienists' evaluation of the patient. The participants' state of dentition was captured because the oral cavities of patients with natural teeth and/or dentures, both of which accumulate dental plaque, are more likely to be colonized with respiratory pathogens than those patients who are completely edentulous

Table 1. Demographic and case history information about participants in the study.

Participant	Sex	Age	Time post admission (years)	Etiology	Comorbidities	Diet	Functional Status	Dental Status
1	M	39	15	Acquired Brain Injury	Hypertension, Diabetes	Oral: chopped food plus thickened liquids	Dependent for feeding and oral care	Dentate
2	F	54	3	Cerebral Palsy	Cervical spondylosis, COPD	Oral: normal diet	Independent with some assistance	Dentate
3	M	55	1	Quadriplegia following motor vehicle accident	Prior drug and alcohol use	Oral: normal diet	Completely dependent	Dentate
4	M	38	9	Intracranial hemorrhage following ruptured arterio-venous malformation	Hydrocephalus	Oral: normal diet	Independent with some assistance	Dentate
5	F	79	12	Multiple Sclerosis	Hypertension, COPD	Oral: normal diet	Independent with some assistance	Dentate with front lower bridge
6	F	78	4	CVA - right internal capsule	Hypertension, Diabetes, COPD	Oral: normal diet	Independent with some assistance	Complete upper dentures, partial lower dentures
7	M	78	1	CVA - right	Hypertension, prior alcoholism	Oral: normal diet	Independent	Dentate
8	M	49	1	CVA - right	Hypertension, Diabetes, COPD	Oral: normal diet	Independent with some assistance	Complete upper dentures, partial lower dentures
9	M	42	3	CVA - brainstem	Prior drug use, Hepatitis C	Prior enteral feeding; now oral, normal diet	Completely dependent	Molar teeth missing
10	M	62	1	CVA - right, post coronary artery bypass graft	Hypertension, Diabetes, COPD	Enteral feeding, nothing by mouth	Completely dependent	Most teeth missing

(Scannapieco, 1999). Furthermore, older adults who retain their natural teeth are at an elevated risk of aspiration pneumonia due to the combination of poor oral hygiene and the periodontal disease that contributes to greater shedding of respiratory pathogens into the saliva (Loesche & Lopatin, 1998).

Two factors were collected through a chart review at the end of the study, to capture events that occurred during the period of observation. First, we documented the use of antibiotic medications, since the long-term use of broad-spectrum antibiotics is reported to lower the colonization resistance of dental plaque, facilitating the overgrowth of non-resident microorganisms (Marsh, 1999). Second, any changes in medical status over the course of the study were captured, with particular attention to respiratory infections.

Oral swabs. Oral swabs were collected from participants at five time-points: a baseline analysis taken prior to their quarterly dental-hygiene appointment, and four follow-up analyses taken at 1, 5, 9 and 12 weeks following baseline. Specimens were collected just prior to lunch in order to reflect the typical lunchtime risk of aspirating pathogenic bacteria that might have accumulated over the course of the morning (i.e. in the time since the provision of *routine* morning oral care). Participants were evaluated under their normal eating conditions (i.e. with or without dentures), and no special procedures were used to cleanse the mouth immediately before specimen collection.

Pathogenic bacteria are known to be readily detectable on the tongue (Van der Velden, Van Winklehoff, Abbas & De Graaff, 1986), which is prone to the accumulation of microorganisms due to its papillary structure and large surface area (Dahan, Timmerman, Van Winklehoff & Van der Velden, 2004). For the current investigation, oral specimens were collected from the dorsal surface of the tongue by sweeping the midline groove in a posterior to anterior direction three times with a sterile oral swab. We chose the tongue swabbing method over swabbing the gingiva or tooth surfaces, because it is likely to gather equivalent data from both dentate and edentate participants. This method was also considered safer than collecting an expectorated oral rinse because it avoids the risk of a rinse spilling into the airway in patients with dysphagia.

Upon removal of the swab from the participant's mouth, it was immediately placed in a sterile specimen container (Amies-Gel with Charcoal Double Swab Kits) and transported to a microbiology lab to undergo standard microbiological analyses (Izenberg, 2003). Transport time to the microbiology lab ranged from 1-2 hours. At the lab, the specimens were plated onto sheep blood agar, chocolate agar, and MacConkey agar and incubated at 35 ºC for 48 hours. Respiratory pathogens (such as *Streptococcus pneumoniae*, *Haemophilus influenzae, Staphylococcus aureus,* and *Pseudomonas aeruginosa*), gram-negative bacilli and *Candida albicans* were identified to the species level using standard techniques. The microbiology report produced a semiquantification (0 = absent, 1 = scant, 2 = light, 3 = moderate, 4 = heavy) of all isolated organisms based on the smear plate method. Tables 2a, 2b and 2c illustrate the results of the colonization analysis by participant and species, across the 5 swabs that were collected. The number of different bacterial species detected served as a crude index of complexity. Total burden was calculated as the number of bacterial species present, multiplied by their semiquantified levels, and is summarized in Table 3.

Salivary flow. As the volume of saliva decreases, the fissures of the tongue may deepen (Limeback, 1988), the oral pH usually decreases (Shay, 2000; Shay & Ship, 1989), and the natural antimicrobial and buffering capacity of saliva reduces. This allows for the proliferation of bacteria (Loesche & Lopatin, 1998) and fungi (Narhi, Ainamo & Meurman, 1993). In order to control for the possible influence of oral dryness on oral colonization, we collected whole saliva measurements immediately following each oral swab using a modified Schirmer test (MST) (Chen, Wai, Lee, Lake & Woo, 2005). This MST used filter paper test strips (Eagle Vision, Memphis, Tenn.), calibrated in 1mm intervals and impregnated with blue dye at the 0mm wick end, which were placed sublingually on the floor of the participant's mouth. When exposed to moisture, the dye travels up the length of the strip; the distance of blue dye travelled was read at a designated interval of one minute.

Data Analyses. Statistical analyses for the study were conducted using SPSS 19.0 software. Chi-square tests were performed to identify differences in the semi-quantified colonization load at each time-point (baseline, 1, 5, 9 and 12 weeks post). Semi-quantified load classes were then collapsed into binary measures (present, absent). Two by two contingency tables for the association between organism presence and respiratory concerns were computed, with Fisher's exact tests used to explore this relationship. A mixed-model repeated measures analysis of variance was performed on the MST data with a repeated factor of time-point to identify differences in the oral dryness measures across swabs.

Table 2a. Semiquantified colonization loads, by species and participant, for successive oral swabs (part 1).

		Neisseria		Viridans Streptococcus		Haemophilus parainfluenzae		Corynebacterium	
Semiquantified Load	Swab#	Frequency	Participants	Frequency	Participants	Frequency	Participants	Frequency	Participants
Light	Baseline	2	p8, p10			3	p6, p7, p8		
	Week 1								
	Week 5					1	p7		
	Week 9								
	Week 12			1	p6			1	p6
Moderate	Baseline					1	p1		
	Week 1					3	p2, p8, p9		
	Week 5	2	p2, p7			3	p1, p3, p8	1	p4
	Week 9	3	p2, p3, p8	3	p2, p3, p8	4	p1, p2, p3, p6		
	Week 12					3	p1, p4, p7		
Heavy	Baseline	3	p4, p5, p6	3	p4, p5, p6	2	p5, p9	1	p4
	Week 1	5	p2, p5, p7, p8, p9	7	p2, p3, p5, p6, p7, p8, p9	6	p1, p3, p4, p5, p6, p7	2	p2, p3
	Week 5	2	p8, p9	3	p4, p8, p9	2	p5, p9		
	Week 9	4	p4, p5, p7, p9	5	p4, p5, p6, p7, p9	2	p4, p5	1	p7
	Week 12	2	p3, p7	1	p3	1	p10	1	p3
Very Heavy	Baseline	5	p1, p2, p3, p7, p9	6	p1, p2, p3, p7, p8, p9			2	p2, p3
	Week 1	3	p3, p4, p10	1	p1			1	p1
	Week 5	4	p1, p3, p5, p10	4	p1, p3, p5, p6			2	p6, p10
	Week 9	2	p1, p10	2	p1, p1o			1	p1
	Week 12	7	p1, p2, p4, p5, p8, p9, p10	7	p1, p2, p4, p5, p7, p8, p9	3	p5, p8, p9	3	p1, p5, p9

Table 2b. Semiquantified colonization loads, by species and participant, for successive oral swabs (part 2).

		Non-Hemolytic Streptococcus		Coagulase Neg. Staphylococcus		Group B Streptococcus		Streptococcus Species	
Semiquantified Load	Swab#	Frequency	Participants	Frequency	Participants	Frequency	Participants	Frequency	Participants
Light	Baseline								
	Week 1								
	Week 5								
	Week 9								
	Week 12							1	
Moderate	Baseline								
	Week 1								
	Week 5			2	p2, p9				
	Week 9								
	Week 12								
Heavy	Baseline	1	p4	1	p8	1	p10		
	Week 1	5	p1, p2, p3, p7, p8					1	p5
	Week 5	2	p7, p8						
	Week 9			1	p6				
	Week 12			1	p3				
Very Heavy	Baseline	3	p1, p2, p3						
	Week 1			2	p1, p4	1	p10		
	Week 5			1	p6	1	p10	1	p6
	Week 9					1	p10		
	Week 12	1	p5	3	p2, p8, p9	1	p10	1	p8

Table 2c. Semiquantified colonization loads, by species and participant, for successive oral swabs (part 3).

		Non-Hemolytic Streptococcus		Coagulase Neg. Staphylococcus		Group B Streptococcus		Streptococcus Species	
Semiquantified Load	Swab#	Frequency	Participants	Frequency	Participants	Frequency	Participants	Frequency	Participants
Light	Baseline								
	Week 1								
	Week 5								
	Week 9								
	Week 12							1	
Moderate	Baseline								
	Week 1								
	Week 5			2	p2, p9				
	Week 9								
	Week 12								
Heavy	Baseline	1	p4	1	p8	1	p10		
	Week 1	5	p1, p2, p3, p7, p8					1	p5
	Week 5	2	p7, p8						
	Week 9			1	p6				
	Week 12			1	p3				
Very Heavy	Baseline	3	p1, p2, p3						
	Week 1			2	p1, p4	1	p10		
	Week 5			1	p6	1	p10	1	p6
	Week 9					1	p10		
	Week 12	1	p5	3	p2, p8, p9	1	p10	1	p8

Table 3. Total colonization burden (the number of identified species, each multiplied by their semi-quantified load), by participant, across successive oral swabs.

Participant	Baseline	Week 1	Week 5	Week 9	Week 12
1	14	18	10	14	14
2	16	11	4	6	12
3	16	14	10	6	12
4	12	15	5	9	14
5	12	13	11	9	20
6§	10	10	18	8	3
7	9	15	6	9	9
8§§	9	14	11	4	20
9	14	14	11	6	20
10§§§	5	9	12	16	15

§Participant 6 developed pneumonia during the course of the study.

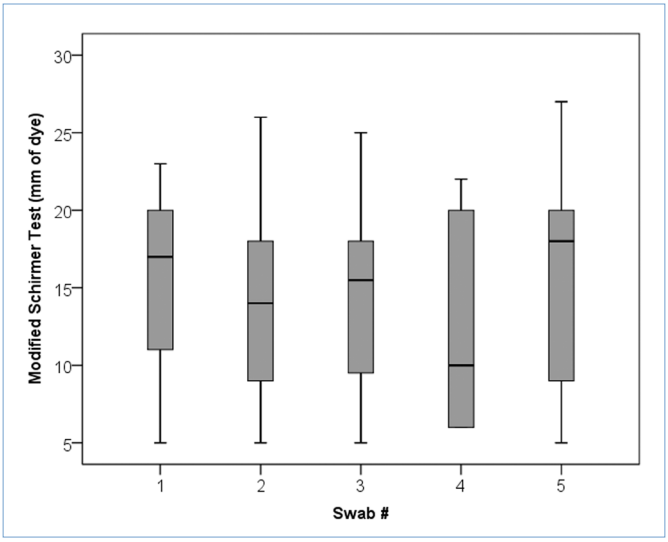
§§Participant 8 developed a cough and congestion and was prescribed antibiotics during the course of the study.

§§§Participant 10, who was the only participant on enteral feeding, is the only participant in whom the predicted trend of increasing colonization burden across successive swabs was observed.

Results

As summarized in Tables 2a, the most prevalent microorganisms in this study were found to be Neisseria species (not *meningitidis* or *gonorrhoeae*), *Viridans*

Figure 1. Means and standard deviation error bars for Modified Schirmer test measures across swabs.



Streptococci, and *Haemophilus parainfluenzae*, which consistently showed heavy colonization across all time-points. These strains are typically classified as commensal (or typical, non-pathogenic) flora in the mouth. Oral colonization with respiratory pathogens was rare in this sample. Colonization with respiratory pathogens did not decrease in response to dental hygiene interventions nor increase with the passage of time as initially hypothesized. In fact, there were no obvious trends in colonization patterns; none of the microorganisms identified in our samples appeared to be disturbed by the dental hygiene interventions.

In our sample, we encountered only two cases of respiratory concern. Participant 6 was medically diagnosed with pneumonia via x-ray and participant 8 was suspected of pneumonia due to cough and congestion and treated as such with antibiotics. In the rare cases where respiratory pathogens of interest were found (i.e., *Staphylococcus aureus* and AGNB) there was no significant association with episodes of respiratory concern amongst our participants. The only exception to this observation was with yeast of types other than *Candida albicans* ($p < 0.01$, Fisher's exact test). Participant 6 (who was diagnosed with pneumonia) was the only individual in our sample who showed colonization with yeast. Given that yeasts are not classified as respiratory pathogens, the clinical significance of this finding is unclear.

Our sample included only one participant on enteral feeding (participant 10). This participant was the only one noted to have a white coating on his tongue and "heavy tenacious calculus" documented in his chart. This participant's oral swabs were unique in showing colonization with Group B *Streptococcus* and *Proteus* species. Notably, as shown in Table 3, this participant was also the only one to exhibit an overall pattern of bacterial load that corresponded to the hypothesized pattern (i.e., lowest load post dental hygiene intervention, then gradually increasing with time).

With respect to measures of oral dryness, the mean MST measure across all swabs was 14.6 mm (SD = 6.8), which is comparable to measures seen in normal healthy individuals (Chen et al., 2005). In all cases except one, the MST measures failed to show oral dryness (i.e., MST measures < 5 mm at 1 minute). MST measures did not fluctuate in any meaningful way across time (see Figure 1). Oral dryness as a factor that may encourage proliferation of pathogens did not appear to be at play in our study.

Discussion

In the current study we observed no particular pattern with respect to the decrease and gradual proliferation of the bacterial pathogens of interest over time in individuals receiving *routine* oral care and quarterly dental hygiene interventions. We could naively interpret these data to show that *routine* oral care was not influencing colonization patterns at all, or that it was effectively limiting pathogen colonization in these patients, and conclude that our data do not argue strongly for a need for better oral care in CCC hospitals. However, the variability of the observed oral ecology gives us grounds to think otherwise. In order to position the current results in a proper context, it would be necessary to fully understand the development/colonization process of dental plaque, the homeostatic mechanisms involved in maintaining oral ecology, and the bacterial/cellular interactions that occur and how these may place patients at risk for pneumonia. While such issues go beyond the scope of this paper, it is apparent to us that a sample size of 10 is inadequate for displaying the oral hygiene-bacterial interactions that are relevant to the pathogenesis of pneumonia. In fact, the biggest lesson we learned in pursuing this study was just how complex the relationship between oral microbial colonization and oral care appears to be. We found that we were left with more questions than answers.

The majority of the bacterial strains identified in the samples collected were determined to be commensal, non-pathogenic microflora of the upper respiratory tract. The most predominant genera of the nasopharynx are *Neisseria, Streptococci,* and *Haemophilus*, which

were the most prevalent microorganisms collected in our samples. These bacteria have also been shown to be the early colonizers in dental plaque development (Liljemark, Fenner & Bloomquist, 1986; Nyvad & Kilian, 1987), and therefore they are thought to play a key role in creating conditions that enable more fastidious organisms to further colonize, leading to the bacterial and structural complexity of dental plaque (Marsh, 2005). *Viridans streptococci* are also reported to be the most numerous bacteria, comprising approximately 40% of cultivable microflora in the oral cavity (Marsh, 2000, p.33). This was the most common strain of bacteria identified in our sample across all swabs (Figure 1).

Anecdotally, the dental hygienists working in the CCC facilities where our study was conducted reported that they considered oral health status to be relatively poor among residents in general. This corroborates the literature showing poor oral health in LTC populations, even following interventions designed to improve the situation (Frenkel, Harvey & Newcombe, 2001). It should, of course, be acknowledged that CCC facilities, in which dental hygiene services are available, probably provide better access to dental care than other types of LTC facilities such as nursing homes. However, our data suggest that the state of poor oral health in the CCC residents who participated in our study was not sufficiently poor to allow for evident colonization with respiratory pathogens. This raises questions about the types of physiological changes that might need to occur in order for an individual in LTC to become susceptible to colonization with respiratory pathogens. Do these changes involve disruption of the early colonizers seen in our data and how do such changes interact with such issues as medical frailty, cognitive status and dependence for activities of daily living? Given that we did not find respiratory pathogens in our small sample, does that mean that these particular individuals were not at risk of developing pneumonia, and would have remained at low risk over a longer timeframe of observation?

Speech-language pathologists, who perform assessments of oral motor and sensory function in adults during in their evaluations of swallowing (CASLPA, 2008), are increasingly interested in patients' oral health as a risk factor for developing pneumonia secondary to aspiration associated with dysphagia. They frequently report that oral health status affects their clinical recommendations for this patient population (Yoon & Steele, 2012) and it has become extremely common for S-LPs to request greater vigilance in oral care for their patients. It is interesting to reflect on the fact that prior literature drawing a connection between oral health and pneumonia risk does not, in fact, suggest that dysphagia is a necessary facilitating factor in this association (Langmore et al., 1998). Thus, the risk of pneumonia for individuals with oral colonization with respiratory pathogens may exist independent of dysphagia, or, it may be the case that future research will demonstrate a heightened risk in those with dysphagia. The current data, collected from individuals residing in LTC suggest that clinical observations of poor oral health status do not add up to reflect colonization that constitutes a clear risk for developing respiratory infection. Furthermore, the three participants for whom dysphagia might have been expected to be a contributing factor were not the ones who developed respiratory concerns during the course of the study. Thus, we conclude that clinicians should be wary of overusing recommendations for vigilant oral care as a mechanism for limiting pneumonia risk, since this appears to reflect an oversimplified understanding of the risk factors involved.

Limitations

There are several limitations in this study that should be taken into consideration for future studies:

1. There was no tracking of the oral care provided by the nursing staff. The type of nursing oral care provided, products used, and the actual time of care delivery relative to the swab collection may have influenced the results of the oral swabs that were collected.
2. The hospitals in which data were collected for this study both have in-house dental services, which provided quarterly dental hygiene appointments to residents. This level of dental service provision is not common to most LTC facilities and, therefore, the definition of *routine* oral care for this study may not be generalizable to other facilities where residents are more likely served by outpatient services.
3. Our sample size was primarily constrained due to budget. The high costs associated with the microbiological testing of oral swabs (i.e., $75.00/swab) render this method of monitoring oral colonization questionably feasible for screening for respiratory pathogens in larger samples or over longer time frames. Even if we had found significant results, we question the merits of swabbing for oral bacteria as a method for tracking pneumonia risk. Clear demonstration of a much stronger relationship would be necessary before recommending more widespread use of this approach. Further, impeccable methods are required to avoid contamination of swabs, and to ensure that species present in oral secretions remain viable in the swab samples up until the point of analysis in a lab.

4. In the current study, we did not stratify our sample for level of dependence in oral care, or for the presence/absence of dysphagia. Both of these factors can impact the risk of developing aspiration-related pneumonia and should therefore be monitored as factors in future, larger studies. In addition, we did not recruit a sufficient number of participants who experienced oral dryness to be able to discern the influence of salivary flow on colonization levels.
5. In an ideal world, we would have continued to add participants to our sample, and would have monitored our participants until we had observed an incidence of pneumonia similar to that reported in the literature. The occurrence of only two candidate episodes in our sample suggests that our study was underpowered to reveal any meaningful relationship between the variables studied and the emergence of aspiration-related respiratory concerns.
6. The oral colonization of the one participant who was on enteral feeding was different from that observed in the rest of the sample. Greater vigilance is required for more vulnerable and complex patients and, therefore, we should have better defined our exclusion criteria, or deliberately sampled a greater number of individuals on enteral feeding.
7. Oral ecology is a variable and complex phenomenon, which fluctuates over time, as shown by the data in this study (Tables 2a, 2b and 2c). The timing of our swab collections was not sufficiently frequent to monitor for rapid changes that might occur. Dental plaque starts to form immediately after being removed, when the early colonizers interact with the pellicle and begin to adhere to the enamel to begin the process; therefore, by the time we collected the first swab following a dental hygiene intervention, it is quite likely that bacteria had already reestablished themselves and the oral environment had already re-stabilized.

Conclusion

Our data did not show any changes in patterns of oral microbial colonization related to dental hygiene interventions over the time-course of our study. No clear relationships were found between oral microbial colonization and symptoms of upper respiratory infection in our pilot sample of LTC residents. We did not find any significant association between measures of oral dryness and the different classes of medications used by our participants, and we did not find that oral dryness measures affected oral bacterial colonization. From this study, we learned that the relationship between microflora and oral care does not unfold in a predictable linear pattern over time. Although our study demonstrated no clear relationships between oral care, oral colonization and respiratory concerns, we would caution that a pilot study does not provide sufficient grounds to challenge previous literature suggesting that oral care may be an effective defensive strategy for managing the risk of developing pneumonia. Our study suggests that speech-language pathologists should be aware that neither dysphagia nor oral colonization are simple or straight-forward mitigating factors for pneumonia pathogenesis. In conclusion, we recommend that speech-language pathologists should collaborate with their colleagues in dental hygiene and nursing to promote good oral health for LTC patients. We caution against the overuse of *routine* recommendations for more vigilent oral care by S-LPs, and recommend that where oral care concerns are identified by an S-LP, interprofessional collaboration to develop patient-centered plans of care should be the preferred approach. Given evidence that efforts to improve oral care provision in LTC facilities face challenges and show poor uptake (Frenkel et al., 2001; Holmes, 1996; MacEntee et al., 1999; Preston et al., 2000; Wardh et al., 2000; Yoon & Steele, 2012), our data suggest that such interprofessional problem solving would be appropriate in situations where there is clear evidence of multiple converging risk factors for pneumonia, including dysphagia, poor oral health and concerns about compromised immune status in a patient.

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