Pneumonia: Factors Beyond Aspiration

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Introduction

Aspiration and its potential danger to the respiratory system were described by Hippocrates in 400 B.C. Later, Hunter in 1781, Simpson in 1898, and Mendelson in 1946 described more clearly the clinical and pathological conditions associated with aspiration, including the potential for death (Chokshi, Asper, & Khandheria, 1986). Clinically, speech-language pathologists are asked to determine the efficiency and safety of the oropharyngeal swallow mechanism and to assist in determining the potential for pneumonia development. A perplexing question, however, is, "Why do some patients with dysphagia who aspirate develop pneumonia and others do not?" The purpose of this paper is to examine factors, other than laryngeal aspiration, that contribute to pneumonia development in some patients.

Pneumonia

Pneumonia is an acute infection and inflammation of the alveoli pulmoni, or pits, at the cellular level of the lungs or its parenchyma (Dasaraju & Liu, 1996). Infection, or the presence of living pathogens within the tissue, develops when the resident immune defenses are insufficient to meet the challenge of bacterial or viral pathogens entering and colonizing the lower respiratory system (Wilson, 2003a). Inflammation is a bodily response that involves the delivery of fluid and immune properties through the blood system to the area of injury or necrosis to counter these invading pathogens. With pneumonia, infection and inflammation begin in the respiratory bronchioles and spread through extracellular fluid spaces over large areas of lung tissue pouring infected exudate into the alveoli. Efficient exchange of oxygen and carbon dioxide is compromised, affecting cell functions throughout the body (Cole & MacKay, 1990; Scannapieco & Mylotte, 1996; Skerrett, 1994; Skerrett, Niederman, & Fein, 1989).

Nosocomial Pneumonia

The diagnosis of nosocomial pneumonia, a subclass of pneumonia, is restricted to people developing the disease while in hospital or nursing facilities (Dasaraju & Liu, 1996; Wilson, 2003b). Nosocomial pneumonia usually has a bacterial origin. Among the more common microorganisms identified as causing nosocomial pneumonia are enteric gram-negative bacteria, or *Staphylococcus aureus*, and gram-negative aerobic bacteria, or *Pseudomonas aeruginosa, Klebsiella pneumoniae,* and *Escherichia coli* (Wilson). Viral-based nosocomial infections are relatively rare, usually seasonal, and caused by exposure to infected persons (Thompson, 1994). Tobin and Grenvik (1984) cited Sanford and Pierce's observations that nosocomial pneumonia is usually not present or incubating at the time of admission, but symptoms begin to appear after the first 48 to 72 hours of admission. At higher risk are those patients who are intubated or in the critical care unit. Thompson reported that hospital stays increase 4 to 13 days in patients developing nosocomial pneumonia. In addition, patients who develop nosocomial pneumonia are at high risk for death.

Aspiration Pneumonia

The larynx is the gatekeeper to the lower respiratory system. In this respect, its function is to prevent entry of foreign materials into the lower airway and to readily expel any foreign materials that may gain entry to the lower airway. Impairment of laryngeal innervation from stroke or impairment of cartilaginous and muscular structures of the larynx from treatments for cancer reduces laryngeal efficiency and impairs the timing of opening and closing. This increases the potential for aspiration. The relationship between laryngeal aspiration and pneumonia has been well recognized (Langmore et al., 1998). However, observational evidence of laryngeal inefficiency and aspiration provides but one piece to the complex puzzle of pulmonary infection.

Marik (2001) defined aspiration pneumonia as an infection that develops after inhaling oropharyngeal pathogens into the lungs that have first colonized in the oropharynx. It represents 8% to 33% of all nosocomial infections (Tobin & Grenvik, 1984). However, the use of the term aspiration pneumonia is not without controversy. Jurado and Franco-Paredes (2001) stated that the use of this term should be discouraged because, "aspiration is a pathogenic mechanism for several inflammatory diseases of the lung, both infectious and noninfectious" (p. 1612). Inhaling large quantities of pathogens into the lower reaches of the respiratory tract is generally recognized as the probable cause of aspiration pneumonia (Jurado & Franco-Paredes, 2001; Skerrett et al., 1989; Tobin & Grenvik). Whether pneumonia develops from one or more episodes of aspiration depends on the volume of aspirated material, the characteristics of the aspirate (e.g., bacterial load, liquid versus particulate matter, pH level), the frequency of aspiration events, and the integrity of the immune system (Johnson & Hirsch, 2003; Langmore et al., 1998; Shockley, 1995). Patients may develop aspiration pneumonia as a response to one episode of aspiration of material. Others may experience epi-

sodes of aspiration pneumonia after aspirating small amounts of material over a longer period of time. They present to their physicians with symptoms including fever, malaise, weight loss, and coughing for one or 2 weeks. Blood screens indicate an elevated immune response, and chest radiographs show lung infiltrates (Johnson & Hirsch; Kannel, Anderson, & Wilson, 1992).

Pneumonia and Illness

Aspiration pneumonia does not develop as a singular and independent disease entity. It is an opportunistic, secondary disease reliant upon the established presence of a serious illness from another disease or medical condition (Bartlett & Gorbach, 1975; Shafazand & Weinacker, 2002). Skerrett and colleagues (1989) reported, "The greater the degree of serious illness in a given patient, the more likely he or she is to have gram-negative colonization of the oropharynx . . ." (p. 470). The increasing severity of the underlying illness or physical disability provides significantly more opportunities for gram-negative bacteria colonization and for pneumonia to develop (Ramphal, 1994). Underlying serious illnesses often associated with aspiration pneumonia include chronic lung disease, cystic fibrosis, chronic cardiac disease, diabetes, malignancy, neurological disorders, azotemia, and renal failure (Salata & Ellner, 1988).

Mechanism of Stress

Serious illnesses are classified as either acute or chronic. An acute condition is an illness or injury that lasts for less than 3 months, was first noticed less than 3 months before initial examination, and is serious enough to have an impact on behavior. A chronic condition is an illness that has not been cured once acquired, such as diabetes, heart disease, birth defects, or amputation. A chronic illness must be present for 3 months or longer (National Center for Health Statistics, 2004).

The onset of a serious illness initiates a highly complex and significant physiological stress response. Stress is defined as the body's reaction to physical, chemical, or emotional forces that cause bodily or mental tension disrupting normal physiologic equilibrium, or homeostasis. The stress response may also be a factor in causing disease (McEwen & Lasley, 2002; Mish, et al., 1986; Spraycar et al., 1995). Homeostasis is constantly challenged by intrinsic or extrinsic adverse forces attempting to disrupt the balance of the body's internal environment (Chrousos, 1998; Sheridan, Dobbs, Brown, & Zwilling, 1994).

The concept of harmony and disharmony in nature dates back over two thousand years. Hippocrates described good health as the harmonious balance of the elements and qualities of life. Disharmony of these elements and qualities was blamed as the cause of disease (Chrousos & Gold, 1992). In the early 1900s, Cannon described the potential effect of stress on the body and introduced the phrase "fight-or-flight response." This phrase referred to physiological reactions necessary to prepare the body to defend itself or to flee. Cannon hypothesized that critical stress levels could alter the body's homeostasis affecting blood sugar and oxygen levels (Carlson, 1994; Chrousos & Gold; McEwen & Lasley, 2002). In the 1930s, Selye described the "General Adaptation Syndrome." This hypothesis suggested that the body has a sophisticated physiological mechanism capable of coping with a variety of challenges (McEwen & Lasley). For brief or milder challenges, the stress mechanism responds but subsides quickly as the body regains equilibrium. In some cases, these challenges are perceived as pleasant and become positive learning experiences. With more severe and adverse challenges, the stress mechanism response is prolonged, and the body is unable to regain complete equilibrium.

If stress responses are sustained for lengthy periods of time, a host of inflammatory diseases, including cardiovascular disease, can develop. Autoimmune diseases may also develop, including asthma, rashes, rheumatoid arthritis, and multiple sclerosis. Secondary effects of these diseases may lead to heart attacks, stroke, headaches, peptic ulcers, and hypertension (Carlson, 1994; Chrousos & Gold, 1992; Kannel, et al., 1992; McEwen & Lasley, 2004). Dysphagia is a common symptom of many of these diseases, with pneumonia as a common secondary illness. If, within the context of the protracted stress response, the abrupt onset of an even more serious challenge occurs, such as a stroke, the stress mechanism increases its response and drives the body further into disequilibrium.

Serious illness, such as stroke or surgery, challenges the survival of the patient. The physiological responses of stress resulting from a serious illness are mediated primarily through neurological, endocrine, and autonomic nervous system interconnections and integrate to maintain homeostasis. Regulation is carried out through two mechanisms: the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS) (Carlson, 1994; McEwen & Lasley, 2002; Sheridan et al., 1994). The hypothalamus is a small structure located at the base of the brain below the thalamus and situated on both sides of the inferior aspect of the third ventricle. Attached to its base is the pituitary stalk leading down to the anterior pituitary gland, which is encased in cranial bone (Hardy & Chronister, 1997; Nolte, 1999). The adrenal glands are small endocrine glands located atop each of the kidneys. The autonomic nervous system is a branch of the pe-

ripheral nervous system and comprises two subsystems: the sympathetic and the parasympathetic nervous systems. These two subsystems have opposite duties. The sympathetic system acts to expend energy from body reserves in times of crisis, while the parasympathetic system acts to restore energy after the crisis has passed (Carlson, 1994). These two systems directly influence salivation and mucous production required for deglutition and immune protection in the oropharyngeal cavities and along the tracheobronchial tree.

In mildly acute illnesses, cells affected at the localized disease site release molecules known as stressors. These stressors enter the blood stream and recruit circulating immune cells called phagocytes. These phagocytes rush to the site of the diseased cells and mount a localized inflammatory response (Sheridan et al., 1994). The illness is isolated and managed locally in a relatively short period of time. Many acutely ill patients may have normal swallowing functions and seldom develop pneumonia.

In seriously acute illnesses, such as stroke or surgery, the localized inflammatory response is unable to contain the spread of disease or injury, and the stressors activate the next higher level of defense—the HPA axis (Carlson, 1994; Chrousos & Gold, 1992; McEwen & Lasley, 2002; Rosmond & Bjorntorp, 2000). The HPA axis is the central physiological mechanism responsible for producing the general adaptation stress response. Using hormones, the HPA axis influences the functions of glands, muscles, hematological properties, and the immune response. As a result, functions related to deglutition and airway protection may be altered. With the onset of a stroke, for example, the HPA axis releases adrenaline into the blood stream. Adrenaline triggers a stronger immune response and activates the sympathetic nervous system. Adrenaline also stimulates immediate changes to heart rate, oxygen intake, glandular output, and peripheral blood vessels (McEwen & Lasley, 2002). Oxygen and glucose reserves are shifted away from maintenance functions of the body such as digestion, growth, and reproduction. These energy sources are sent to muscles and organs critical to immediate survival (Chrousos, 1995). Reduction in salivary gland secretions and restriction of capillaries result in significant changes to the environments of the oropharyngeal cavities and the lower respiratory tract inviting gram-negative bacteria colonization.

Later, as the illness is contained by the immune system, the HPA axis responds to the elevated levels of adrenaline by producing additional hormones that will restore homeostasis. The primary stress hormone is cortisol which is released from the adrenal glands. Cortisol activates the parasympathetic nervous system to begin reducing the stress response. Much like a thermostat, cortisol acts to slow down the stress response, which in turn reduces the immune response. Consequently, inflammation and swelling from tissue damage are reduced. In addition, heart rate reduces, blood vessels dilate, glandular functions increase, and energy stores are replenished (McEwen & Lasley, 2002).

As mentioned earlier, certain diseases may result from the sustained stress response. In some severe acute and chronic illnesses, the HPA axis does not regulate properly. Overproduction of cortisol leads to hypercortisolemia. Of significance to developing pneumonia, this condition causes the immune system to become immunosuppressive, or "turning on itself." Immunosuppression allows pathogens to greatly increase and infections to continue unabated (Schteingart, 2003). Olsson, Marklund, Gustafson, and Näsman (1992) compared cortisol levels in CVA patients to cortisol levels in normal subjects. The hypercortisolemia that was found to be common among CVA patients correlated positively with acute confusion and extensive motor impairment. Furthermore, high levels of cortisol were associated with poorer functional outcomes and higher mortality. Similar findings were reported by Fassbender, Schmidt, Mossner, Daffertshofer, and Hennerici (1994). Slowik and colleagues (2002) compared cortisol and other blood products levels of 70 CVA patients and 24 matched controls. Patients were followed for 90 days. Results indicated that hypercortisolemia was associated with old age, greater neurological deficits, larger ischemic lesion on CT, and worse prognoses. Prolonged hypercortisolemia has also been associated with chronic underlying diseases such as diabetes, cardiovascular and cerebrovascular diseases, and hypertension (McEwen & Lasley, 2002).

It is now apparent that the onset of illness, whether acute or chronic, initiates a dramatic counter-response by the body to protect and repair itself. Following the initial response to pathogenic processes, a counter-response can alter normal immune, glandular, and muscular functions. These changes may jeopardize the safety and efficiency of deglutition and safety of the lower respiratory system.

Immune Functions

The immune system responds to illness by sending increased numbers of phagocytes into the bloodstream and to the site of inflammation. Phagocytes, or white blood cells, make up about 1% of the blood's composition and specialize to serve a number of immune functions. Among these specialized cells, neutrophils are predominant. Their function is to specifically seek out and destroy bacteria (Janeway, Travers, Walport, & Shlomchik, 2001; Miyaski, 1991). Neutrophils

are part of the initial immune response and take one to 3 hours to arrive at the site of the inflammation (Cole & MacKay, 1990). Janeway and colleagues state that this initial immune response requires 4 to 7 days before producing a significant effect at the inflammation site. This coincides with Skerrett's (1994) observations that the primary response by the immune system to pneumonia requires 5 to 7 days. These findings support Sanford and Pierce's observations, as cited by Tobin and Grenvik (1984), that symptoms of nosocomial pneumonia are usually not present at the time of admission, but begin to appear after the first 48 to 72 hours of admission.

The high risk of developing pneumonia within the first week following the onset of a serious illness is a significant clinical factor when assessing for dysphagia and potential aspiration. Decisions to feed or not to feed should be influenced by the current status of the immune system. In acute care settings, current blood test results are available in the patient's medical record. Abnormally high white blood cell and, more specifically, neutrophil counts should alert the examining clinician that an infection exists and is not controlled. An elevated neutrophil count in concert with demonstrated laryngeal aspiration provides ample evidence that conditions are optimal for pneumonia to develop. Pneumonia will not occur unless both of these key factors are present.

Oropharyngeal and Tracheobronchial Environments

Stress response activation reduces saliva and mucous production in the upper and lower respiratory systems. Saliva glands and mucous glands have rich blood supplies and are regulated by the ANS. These glands manufacture and transport saliva and mucous and their protein enzymes to the oropharyngeal cavity and the tracheobronchial tree to maintain environmental homeostasis. The viscosity of the mucous and saliva entraps bacteria. The proteins in these secretions destroy the bacteria or inhibit them from adhering to the mucosa or cavity surfaces and colonizing (Bartlett & Gorbach, 1975; Gibson & Barrett, 1992; Scannapieco & Mylotte, 1996; Stockley, 1995). In healthy persons, one cubic centimeter of saliva contains approximately 10^8, or 100,000,000, bacterial pathogens that populate the oropharyngeal cavities at any given time (Langmore et al., 1998; Skerrett, 1994). Aspiration of 0.01 ml of oral contents (secretions, water, or food) can introduce 10^6 to 10^8 pathogens into the lower respiratory system (Tobin & Grenvik, 1984). Johanson, Pierce, and Sanford, as cited by Salata and Ellner (1988), reported that bacterial colonization of the oropharynx was found in 6% of normal individuals, 35% of moderately ill patients, and 73% of severely ill patients. A strong relationship has been shown between oropharyngeal bacteria and development of pneumonia (Mojon, 2002; Russell, Boylan, Kaslick, Scannapieco, & Katz, 1999; Scannapieco, 1999; Watando et al., 2004). With severe illness and activation of the HPA axis, the blood supply may be restricted, reducing levels of salivary and mucous enzymes manufactured by these glands. This decreases epithelium protection and allows increased bacterial colonization during illness (Scannapieco). Colonization occurs when bacteria penetrate the oral epithelium and adhere to the surfaces of the teeth. Here bacteria feed off of extracellular fluids and multiply (Peterson, 1996). Reduced volume and availability of these protective secretions permit rapid colonization. Within 12 hours, without adequate immune control, these bacteria can increase nearly 2.5 times (Stockley). Langmore and colleagues reported predictors of aspiration pneumonia among hospital patients and nursing home residents. Among the predictors were the number of decayed teeth, the number of medications taken, multiple medical diagnoses, and smoking. These factors alter the environmental integrity of the oropharyngeal cavity and the lower respiratory tract. Terpenning and colleagues (2001) reported a significant prevalence of decayed teeth and visible dental plaque among a group of patients with aspiration pneumonia. Many medications dehydrate the mucosa reducing epithelium protection. Smoking impairs the ciliary action of the mucociliary escalator reducing its ability to remove debris and pathogens from the airway. These findings support the need for good oral care of hospital patients and nursing home residents to help reduce growth and colonization of bacteria in the airway tracts (Watando et al.).

Muscle Functions

With activation of the stress response, increases in adrenaline result in extraction of fatty acids, amino acids, and glucose from skeletal muscles and from adipose tissue. These fuels are sent to visceral organs to ensure their vital functions and to repair tissue injury (Wilmore, 2000). The result is a reduction in available energy for the mechanisms of digestion, including the muscles of deglutition. Seriously acute illness also reduces levels of oxygen and iron in the blood stream resulting in weakness of the slow and fast twitch muscle fibers necessary for efficient swallowing (Chi-Fishman & Pfalzer, 2003; Hudson, Daubert, & Mills, 2000). With prolonged illnesses, this marked catabolic response may result in protein wasting and loss of lean body mass, which in turn, leads to impaired immunity, poor wound healing, and muscle weakness (Hadley & Hinds, 2002). Weakness of the oral and pharyngeal muscles may result in delayed swallow onset, reduced oral and pharyngeal peristalsis, and inefficient laryn-

geal opening and closing, which increases the risk of aspiration. Coupled with low red blood cell count, low hemoglobin and hematocrit values, an imbalance of electrolytes, and an elevated immune response, seriously ill patients become systemically debilitated. This condition is characterized by weakness, lethargy, and lack of energy, each with the potential of affecting swallowing and respiratory safety. Low counts among the red blood cell measures indicate a reduced ability to deliver oxygen and glucose to cells. Low red blood cell count and high white blood cell count are biochemical indicators of generalized debility. General debilitation affects oral, pharyngeal, and laryngeal efficiencies and may be responsible for dysphagia and aspiration

Conclusion

Laryngeal aspiration is not the sole cause of aspiration pneumonia. Aspiration pneumonia can only develop within the context of a primary and serious illness. A physiological stress response resulting from the onset of illness alters the neurological, endocrine, and immune systems to counteract the physiological effects of the illness and regain homeostasis. Clinicians should be aware of the complexity of serious illness and how the alterations to major systems of the body can lead to dysphagia and pneumonia. Assessment and treatment should move beyond observations of potential aspiration events and their causes and place these findings within the context of the patient's total medical condition. Use of available information, such as diagnostic reports and laboratory values, will provide insight into the patient's overall state of health and the various processes involved in recovery.

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Continuing Education Questions

1. Pneumonia is an acute inflammation and infection of the lung parenchyma. This inflammatory and infectious process begins

a. in the trachea and spreads throughout the bronchi.

b. in the alveoli pulmoni and spreads from one pulmonary unit to the next infecting large segments of the lung.

c. in the respiratory bronchioles and spreads through extracellular spaces to the parenchyma.

d. in the rich capillary supply surrounding each alveoli pulmoni and spread through extracellular spaces to the parenchyma.

2. Aspiration pneumonia can develop only

a. because the body's immune system is weak.

b. as a result of poor laryngeal closure efficiency.