Nurse Practitioners: Limiting the Trade-Off between Quality and Cost

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Nurse Practitioners: Limiting the Trade-Off between Quality and Cost

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Economics
Advisor: Professor Maxwell
Introduction

Health care expenditures as fraction of the United States’ gross domestic product are growing at an unsustainable rate (Kimbuende, 2010). In 2008, national health expenditures totaled over $2.3 trillion or 16.2% of GDP (Kimbuende, 2010). By 2009, spending had increased to almost $2.5 trillion or 17.6% of GDP (Wilson, 2011). Despite this high level of spending in comparison to other developed countries, the average American citizen does not appear to be receiving significantly better care (Kimbuende, 2010). Even within the United States, geographic variation in health related spending has been shown not to correlate with improved health status. Based on this observation, some analysts have estimated that as much as 30% of health care spending is unnecessary (Kimbuende, 2010). Though inefficiency in the health care delivery system is unlikely to be eradicated in the near future, this marked disparity in spending and product value suggests substantial room for improvement.

With spending on physician and clinical services accounting for as much as 21% of national health expenditures in 2008, decreasing physician time costs could have a considerable impact on total expenditures (Kimbuende, 2010). Employing nurse practitioners in addition to or in place of physicians has been suggested as one method of increasing efficiency. Nurse practitioners undergo much less costly training than physicians and are typically paid significantly lower salaries than doctors. Despite this lower direct input cost, nurse practitioners have been shown to provide a level of care comparable to that of physicians in many areas of health care. Using nurse practitioners to provide comparable care at lower costs decreases market inefficiency, lowering costs without imposing any significant sacrifice in quality.

Training costs and salaries are just two factors that impact the overall economic value of employing nurse practitioners. Another important factor to consider is the cost of delivered
treatment. This thesis is designed to assess the cost differences in ear infection treatment as provided by nurse practitioners in comparison to treatment as provided by physicians.

**Background**

Health reform is often referred to as a “three-legged stool” incorporating access, quality and cost. When operating efficiently, a sacrifice in access and/or quality is necessary to achieve lower costs. However, due to the current inefficiency in the health care market, it may be possible to achieve lower costs without sacrificing either access or quality.

**Access**

Patients seeking care in the United States currently face a deficit of primary care providers. The aging population and expanded roles of primary care providers have put increased pressure towards expansion on provider groups in this market (Laurant, 2004). Demand for care and shortfalls in physician supply are projected to grow, increasing the already substantial pressure on the primary care market. Health care reform is expected to expand coverage, further increasing demand as more people gain access to healthcare. However, the number of primary care physicians and these doctors’ work hours are expected to decrease in response to lower reimbursement rates, decreasing the already limited supply of primary care providers (Park, 2011; Raedle, 2010).

Nurse practitioners offer a way to fill the gap between supply and demand. One study showed that 25-70% of work done by physicians could be transferred to nurses (Laurant, 2004). Nurse practitioners are often shown to provide access to care with shorter wait times. By acting as physician substitutes, nurse practitioners allow doctors to delegate more routine tasks and instead focus on more complicated health problems. Acting as supplements, nurse practitioners
can provide care and counseling that physicians themselves might otherwise not have the time to offer.

Quality

Many studies have assessed the quality of care provided by nurse practitioners. These studies have compared nurse practitioners’ patients’ disease outcomes such as morbidity, mortality, quality of life, patient satisfaction and compliance with the outcomes achieved by physicians. Researchers conducting these studies also often evaluate nurse practitioners’ compliance with care standards, assessing whether or not nurse practitioners follow treatment guidelines similar to those employed by physicians (Laurant, 2004).

Though nurse practitioners are not trained to perform all of the functions traditionally reserved for physicians, they have been shown to provide a comparable level of care in many specific primary care situations. For example, a randomized controlled trial performed by Schuttelaar, Vermeulen, and Coenraads showed that compared to dermatologists, nurse practitioners achieved a similar level of treatment effectiveness and higher parent satisfaction when caring for children with eczema (Schuttelaar, 2011). In a similar study where nurse practitioners were compared to gastroenterologists, the nurse practitioners were shown to provide similar levels of accuracy, safety and satisfaction in performing colonoscopies (Limoges-Gonzalez, 2011).

Besides achieving desirable treatment success rates, nurse practitioners have also been shown to improve patient satisfaction. Being able to spend more time with patients, nurse practitioners have been shown to provide more comprehensive explanations of procedures and ailments and better instructions for self-care. A recent study of community health centers found that 53% of visits completed by a nurse practitioner included documented health education or
counseling services, whereas only 42% of physician completed visits incorporated such services (Hing, 2011).

Cost

Because nurse practitioners typically receive lower salaries than physicians, many health economists predict that nurse practitioners are capable of providing lower cost care. However, salary is not the only factor that influences the overall cost of care.

Nurse practitioners tend to spend more time per visit than do physicians. This difference in time investment means that nurse practitioners are able to complete fewer visits per hour than physicians. In other words, nurse practitioners generate less revenue per input unit of time than doctors even when both are providing the same service. Consequently, though nurse practitioners cost less per hour, this cost benefit is counterbalanced and may even be negated by their lower productivity.

Furthermore, nurse practitioners may need more assistance, for example being able to consult with physicians before providing treatments, in achieving the same outcomes as physicians. Higher referral rates, increased use of diagnostic tests, increased prescription use and/or more required follow-up appointments could also offset the cost benefit gained from nurse practitioners’ lower salaries. Additionally, some nurse practitioners may need physician supervision. In this case the combined cost of the nurse practitioner and the physician may be greater than the physician’s cost alone even if nurse practitioners are able to significantly lower physician time investment.

One way to assess the economic efficiency of nurse practitioners is to determine whether or not nurse practitioners are able to earn back their own cost of employment. This could be achieved either directly through reimbursement for completed consultations or indirectly by
allowing a practice or hospital as a whole to expand care to a greater number of patients. A Dutch study observing nurse practitioners’ effect on practice growth showed that, mainly due to economically inefficient use of the physician time saved, most nurse practitioners in the Netherlands did not make back their own cost of employment. On average, only 27% of the time physicians gained by delegating tasks to nurse practitioners was allotted to expanding their practice (Dierick-van Daele, 2011). Physicians tended to spend a significant amount of the time saved by nurse practitioners on activities not related to practice growth. For example, doctors chose to put more time towards quality improvement, treating more complex patients, and non-patient related activities such as research, tasks that often do not in themselves generate additional revenue and consequently do not appear economically beneficial in a study directed exclusively at profit analysis (Dierick-van Daele, 2011).

Though the Dutch study showed that, from a business standpoint, the nurse practitioners observed were not profitable to the practice, this analysis systematically excluded significant economic outcomes. Shorter wait times achieved by nurse practitioners would allow patients to return to work sooner, increasing their productivity. Unreimbursed tasks, such as working to improve coordination of care and thereby reducing duplicate procedures, could reduce total costs billed to insurance companies. Though not directly affecting the practice in consideration’s profits, these costs would likely have a significant impact on overall total costs and consequently national spending.

Other researchers have made efforts to assess the indirect savings associated with nurse practitioner care. Alnoor Hemani gathered data on resource utilization per patient over the course of one year. By observing total annual spending on tests, specialty care, primary care, hospitalizations, and emergency or walk-in visits he concluded that on average nurse
practitioners tend to utilize more resources than physicians, increasing total costs (Hemani, 1999). Taking another approach, Val Lattimer conducted a study assessing the impact of additional nurse practitioner services in terms of reducing expenses due to emergency hospital admissions. Though she found that the cost of implementing an extended telephone consultation program was £81,237 per year, she found that these costs were counterbalanced by £94,442 in emergency room savings, resulting in an overall decrease in total costs (Lattimer, 2000).

Based on the lack of consistency in methods and results, it is clear that the economic efficiency of nurse practitioners must be assessed on a job specific basis. Nurse practitioner productivity and financial viability vary depending on the specific type of care the nurse practitioner is intended to provide.

**Purpose**

Though much research has been done on the subject of substituting nurse practitioners for physicians as health care providers, both analytic methods and results have been inconsistent. Various studies have shown nurse practitioners to provide equivalent or improved care especially in primary care settings. However, no consensus has been reached on whether or not and under what conditions this substitution is economically efficient. Because of variation in productivity and substitution rates, the economic viability of nurse practitioners must be assessed on a department specific basis, taking into account differences in nurse practitioners’ job descriptions.

One specific area this economic efficiency could be assessed in is in the diagnosis of ear infections. A study conducted through the National Ambulatory Medical Care Survey and the National Hospital Ambulatory Medical Care Survey showed that 15% of pediatric visits included a diagnosis of middle ear infection (Freid, 1998). If employed properly, nurse practitioners could be used to achieve significant cost savings in this area.
This thesis is intended to address the economic efficiency of nurse practitioners as compared to physicians in diagnosing ear infections. First nurse practitioner quality in this specific area will be assessed by comparing nurse practitioner diagnosis error rates to physician error rates based on surveys asking both types of providers to provide diagnoses based on tympanic membrane images collected through previous telemedicine visits. Next the economic practicality of employing nurse practitioners in this field will be assessed in terms of the relative costs of these errors, measured as the cost of unnecessary prescriptions in the case of overdiagnosis and the cost of an unnecessary follow-up visit in the case of underdiagnosis.

Methods

Participant Selection

During the summer of 2011, 140 pediatric clinicians at Golisano Children’s Hospital of the University of Rochester Medical Center were sent recruitment e-mails (Appendix A) requesting their participation in an online ear infection diagnosis study and offering a $10 Amazon gift card in appreciation for their effort. These clinicians included both physicians and nurse practitioners with a variety of levels of both traditional clinical experience and telemedicine experience. Though previous experience with telemedicine was not required, all participants were required to have some prior pediatric experience and training. Thirty four providers, or 24.3% of providers contacted, responded to these recruitment e-mails indicating that they would be willing to participate.

Because no previous telemedicine experience was required, all participants were asked to complete an online telemedicine training course (Appendix B) before being given access to the study surveys. This 20 minute course, designed specifically for this study, both detailed the
criteria for diagnosing acute otitis media (AOM) and presented participants with sample telemedicine images retrieved in the same manner as those used in the surveys.

Image Selection

After taking this online course, each participant was given password-protected access to a diagnosis based survey. In the survey, study subjects were shown a set of ear images. Using these images as the basis for the study subjects’ diagnoses instead of in-person evaluation ensured consistency in the information providers received on which to base their diagnoses. These images were selected from a database of over 10,000 tympanic membrane images collected through telemedicine visits completed between May 1, 2001 and December 31, 2010 (Figure 1).
To begin the selection process, 9500 visits were selected from those stored in TeleAtrics, a computer program used to facilitate telemedicine visits. These visits were selected because, based on the primary associated diagnosis, they were likely to contain ear exam data. The selected diagnoses included strep pharyngitis, viral illness, otitis externa, otitis media with effusion (OME), AOM, AOM with rupture of TM, chronic suppurative otitis media, ear drum perforated nos, tinnitus, ear pain, hearing loss, acute sinusitis, pharyngitis nos, URI, allergic
rhinitis, influenza, cough variant asthma, and febrile illness. Visits associated with other primary diagnoses, making them unlikely to contain ear images, were excluded.

To reduce the time cost associated with collecting and processing images, 450 visits were then randomly selected from the original 9500 visits. These visits were divided into 15 groups of 30 visits each for the remainder of the selection process. All ear images from these 450 visits were collected, after which 383 total visits with ear images remained; twenty three visits had to be removed because they were not found in TeleAtrics and 44 were removed as they did not contain any ear images. Next the collected images were all reviewed and those with low resolution were removed. Through this process, an additional 44 visits with only poor quality images were rejected, leaving 339 visits remaining.

The visits were then separated into left and right ear groups. Twenty-five right ears and 40 left ears were removed as they were represented by only poor quality images. This left a pool of 314 right ears and 299 left ears for a total of 613 remaining ears. Thirty of these remaining ears were randomly selected from each of the 15 original visit-associated groups, resulting in a pool of 450 ears total.

The selected images were reviewed by Dr. Kenneth McConnochie to verify their diagnostic quality. During this expert review process 22 right ears and 22 left ears were removed because the images were not representative of the same ear, the tympanic membrane was not visible in the image (for example because it was obscured with cerumen or only part of the drum was shown in the image), poor lighting could not be improved by adjusting brightness and/or contrast, glare obscured the image, and/or because insufficient detail was shown. Replacement ears from the same diagnosis category: AOM, OME, or no effusion present, were selected from the same initial assessment group whenever possible. For example, those ears randomly assigned
to be used in Survey 1 that were not initially selected were used to replace the images from the same diagnosis category that were rejected from Survey 1. The brightness and/or contrast were also adjusted in some of the images as this feature is available to providers within the TeleAtrics program and would have been available to the providers making the initial telemedicine diagnosis.

As can be seen in Figure 1, the proportions of the three diagnoses remained relatively constant throughout the selection process. This was important in avoiding introducing bias by selecting disproportionately for a given diagnosis. A question asking participants to assess the quality of the images was also included in the survey to verify that the selection process was not overly stringent, allowing only exceptional quality images to be included. Both images ranked by study participants as high quality (Figure 2) and low quality (Figure 3) can be seen below.

Survey Design

The survey was designed so that each participant would be able to view all selected images of the ear they were being asked to diagnose but could not view images of other ears while making their diagnoses. This was designed to simulate the conditions of the original provider who would have been unable to compare different patients’ ears when making his or her diagnosis.
For each ear, participants were first asked to determine whether or not the tympanic membrane was opaque, erythematous, and/or bulging, criteria for making a diagnosis of AOM. They were then asked to choose one of three diagnosis options: AOM, OME, or no effusion present. Additionally, participants were asked to rate their level of confidence in the diagnosis and the quality of the images.

After completing the diagnostic portion of the survey, each participant was asked to indicate what type of clinician they were, in this case physician or nurse practitioner, indicate about how many telemedicine visits they had completed in the past (zero, 1-20, 21-100, or >100), and in the case of physicians give some indication of their level of pediatric experience by stating how recently they had graduated medical school (0-3, 4-10, 11-20, or >20 years ago).

One page of a sample assessment is shown in Figure 4 below.
Survey Distribution

Fifteen versions of the survey, each containing images of 30 different ears, were created. Each was designed to be sent to four different participants for a total of 60 study subjects. Each version of the survey was first randomly assigned to one nurse practitioner and one physician. The remaining surveys were then randomly assigned to the participants who had not already been assigned to complete a specific survey. This process ensured that each set of ear images would be observed by at least one nurse practitioner and one physician for comparison purposes. Participants were not granted access to the surveys until after they had completed the online training course.

Data Collection

Both participants’ diagnoses as determined through the study surveys and the original visit diagnoses were collected. These diagnoses will be referred to as the survey diagnosis and the original diagnosis respectively. As the original diagnoses were recorded by child as opposed to by ear, survey diagnoses were combined to facilitate comparison such that the patient was considered to need antibiotics if the study participant diagnosed either ear as having AOM. For example, if a participant diagnosed patient X’s right ear as having no effusion present and the left ear as having AOM, the survey diagnosis would be recorded as AOM as the child would be treated with antibiotics regardless of whether one or both ears was diagnosed with AOM. This overall survey diagnosis of AOM would then be compared with the original diagnosis recorded for the child during his or her initial visit.

Definition of Significant Difference

Because both diagnoses of OME and no effusion present require no antibiotic treatment, these two diagnoses were not considered significantly different. For example, cases where an
original diagnosis indicating no effusion present was recorded while the survey participant diagnosed the ear as having OME were not considered to indicate disagreement (Table 1). However, cases where either the original diagnosis or the survey diagnosis indicated AOM while the other diagnosis indicated no effusion present or OME were considered significantly different. This is because AOM is traditionally treated with antibiotics while neither OME nor a diagnosis of no effusion present warrants this treatment.

<table>
<thead>
<tr>
<th>AOM</th>
<th>OME</th>
<th>No Effusion Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Difference</td>
<td>Significant Difference</td>
<td>No Significant Difference</td>
</tr>
<tr>
<td>Significant Difference</td>
<td>No Difference</td>
<td>No Significant Difference</td>
</tr>
<tr>
<td>Significant Difference</td>
<td>No Significant Difference</td>
<td>No Difference</td>
</tr>
</tbody>
</table>

Table 1: Significance of Diagnosis Differences

Determining Cost

Disagreement costs were considered in terms of either unnecessary prescription costs or the cost of a return visit.

In the case of overdiagnosis, the cost of disagreement was considered to be the cost of unnecessary prescriptions (Table 2). This cost was calculated as the weighted average cost of antibiotics commonly prescribed to treat otitis media in Seattle. The 2011 total average costs, including both costs paid by the insurer and by the patient’s guardian, of amoxicillin, cephalospor, cipro, sulfa, and zithromycin were weighted so those antibiotics prescribed more or less frequently factored proportionally into the final average prescription cost of $25.25.

<table>
<thead>
<tr>
<th>Year</th>
<th>Drug Group</th>
<th>N</th>
<th>Average Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Amoxicillin</td>
<td>384</td>
<td>16.18</td>
</tr>
<tr>
<td>2011</td>
<td>Cephalospor</td>
<td>59</td>
<td>54.05</td>
</tr>
<tr>
<td>2011</td>
<td>Cipro</td>
<td>21</td>
<td>111.54</td>
</tr>
<tr>
<td>2011</td>
<td>Sulfa</td>
<td>13</td>
<td>24.25</td>
</tr>
<tr>
<td>2011</td>
<td>Zithromycin</td>
<td>146</td>
<td>25.14</td>
</tr>
</tbody>
</table>

Table 2: Commonly Prescribed Antibiotic Costs, Source: City of Seattle, Nick Maxwell
In the case of underdiagnosis, the cost of disagreement was considered to be the cost of an additional visit necessary to achieve the correct diagnosis and receive appropriate antibiotic treatment (Table 3). This amount did not include prescription costs as patients with otitis media would incur this cost whether they were prescribed antibiotics at their initial visit or at a follow-up visit. Again the average cost was determined based on the 2011 average total costs paid by the insurer and the patient’s guardian, for a final average disagreement cost of $317.52.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Return Events</th>
<th>Average Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>96</td>
<td>317.52</td>
</tr>
</tbody>
</table>

Table 3: Return Visit Costs, Source: City of Seattle, Nick Maxwell

**Results**

Nurse practitioner and physician disagreement rates and the associated costs were compared to determine the economic efficiency of employing nurse practitioners in diagnosing ear infections. Both clinical experience and experience with telemedicine were controlled for. In the following four tables the uppermost number in each cell represents the mean impact $\mu$, the middle number (in parenthesis) represents $\sigma$, and the lower number represents the number of observations in each category.

<table>
<thead>
<tr>
<th></th>
<th>Zero TM</th>
<th>1-20 TM</th>
<th>21-100 TM</th>
<th>&gt;100 TM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NP</strong></td>
<td>0.632</td>
<td>0.700</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(0.496)</td>
<td>(0.483)</td>
<td></td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>10</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td><strong>MD</strong></td>
<td>0.667</td>
<td>0.750</td>
<td>0.900</td>
<td>0.733</td>
</tr>
<tr>
<td></td>
<td>(0.485)</td>
<td>(0.463)</td>
<td>(0.316)</td>
<td>(0.458)</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 4: Impact of Telemedicine Experience on Agreement

Table 4, where $\mu = 1$ represents perfect agreement, shows the impact of prior experience with telemedicine on average disagreement rates. Agreement tended to increase with more telemedicine experience, except for the category of physicians who had completed over 100
telemedicine visits prior to participating in the study. No nurse practitioner subjects had completed 21-100 telemedicine visits prior to participating. Clinical experience, accounted for amongst physicians using the proxy variable of years since graduating medical school, had a similar effect of increasing agreement as shown in Table 5. Having graduated from medical school more than 20 years ago broke this trend, decreasing agreement rates. This may be because older physicians are less comfortable with new telemedicine technology.

<table>
<thead>
<tr>
<th>MD</th>
<th>0-3 MD</th>
<th>4-10 MD</th>
<th>11-20 MD</th>
<th>&gt;20 MD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.667</td>
<td>0.900</td>
<td>1</td>
<td>0.625</td>
</tr>
<tr>
<td></td>
<td>(0.485)</td>
<td>(0.316)</td>
<td>(0)</td>
<td>(0.500)</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>10</td>
<td>7</td>
<td>16</td>
</tr>
</tbody>
</table>

*Table 5: Impact of Clinical Experience on Agreement*

Tables 6 and 7 show the impacts of telemedicine experience and clinical experience on costs. These effects, however, appear to be insignificant.

<table>
<thead>
<tr>
<th>NP</th>
<th>Zero TM</th>
<th>1-20 TM</th>
<th>21-100 TM</th>
<th>&gt;100 TM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD</td>
<td>9.30</td>
<td>7.57</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(12.51)</td>
<td>(12.20)</td>
<td>-</td>
<td>(0)</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>10</td>
<td>(0)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>(12.25)</td>
<td>(11.69)</td>
<td>(7.98)</td>
<td>(81.25)</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

*Table 6: Impact of Telemedicine Experience on Disagreement Cost*

<table>
<thead>
<tr>
<th>MD</th>
<th>0-3 MD</th>
<th>4-10 MD</th>
<th>11-20 MD</th>
<th>&gt;20 MD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.42</td>
<td>2.52</td>
<td>0</td>
<td>27.74</td>
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<tr>
<td></td>
<td>(12.25)</td>
<td>(7.98)</td>
<td>(0)</td>
<td>(78.19)</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>10</td>
<td>7</td>
<td>16</td>
</tr>
</tbody>
</table>

*Table 7: Impact of Clinical Experience on Disagreement Cost*

**Econometric Analysis**

Multiple different types of regressions and tests were performed in order to first compare the quality of service provided by physicians and nurse practitioners and then to assess the cost effectiveness of employing nurse practitioners to treat ear infections.
As shown in Figure 5, when telemedicine and clinical experience are controlled for, physicians tend to be less likely than nurse practitioners to disagree with the original diagnosis. The first variable shown in the figure, MD, is a dummy variable equal to 1 for subjects who are physicians and 0 for nurse practitioner participants. The following three variables, MD1 through MD3, are also dummy variables indicating levels of clinical experience such that MD1 indicates that the physician graduated from medical school 0-3 years ago. This data was not collected for nurse practitioners, thus the value of this variable was always zero for participants who were nurse practitioners. Though the predicted sign of the MD coefficient is negative, indicating that physicians with more than 20 years of experience would be more likely than nurse practitioners to disagree with the original diagnosis, when combined with the coefficients accounting for physician experience the predicted sign is almost always positive. For example, physicians who graduated medical 0-3 years prior to participating and those who graduated medical school 11-20 years prior to participating were shown to be more likely to agree with the original diagnosis. The results produced through logit and probit regressions (Appendices C and D respectively) were qualitatively similar, showing that physicians tended to disagree with original diagnoses less frequently than nurse practitioners.
Though these results support the hypothesis that physicians are more accurate in their diagnoses, the difference in agreement rates is relatively small. Consequently, hospitals and clinics should still consider employing nurse practitioners to diagnose ear infections as this small difference in quality could easily be outweighed by cost savings.

However, when telemedicine and clinical experience are controlled for, physicians also tend to make less costly errors (Figure 6). Again, the variables shown are defined such that MD indicates whether the participant was a nurse practitioner or a physician and MD1-MD3 indicate the physicians’ level of clinical experience. Combining the coefficients for provider type and clinical experience, physicians are shown to be less costly in terms of return visit costs and unnecessary prescriptions. Again, however, the cost difference between nurse practitioners and physicians is relatively small.
These results are summarized in Figure 7, which also demonstrates the importance of controlling for both telemedicine and clinical experience.
These results were confirmed by a secondary analysis using a multinomial logistic regression. The results are shown in Figure 8, where the upper section shows the probability of falling into the category of overdiagnosis, costing on average an additional $25.25, and the lower section shows the probability of falling into the category of underdiagnosis, costing on average an additional $317.52. The category of no significant difference in diagnosis and consequently no additional cost due to imprecise diagnosis was used as the base.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td>MD</td>
<td>-0.0976</td>
<td>-0.148</td>
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<td>6.428</td>
<td>22.00*</td>
<td>25.96*</td>
</tr>
<tr>
<td></td>
<td>(-0.31)</td>
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<td>(-1.82)</td>
<td>(0.93)</td>
<td>(2.25)</td>
<td>(2.42)</td>
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<td>0.282</td>
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<td>-26.85</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.28)</td>
<td>(1.45)</td>
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<td>(-1.75)</td>
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<tr>
<td>MD2</td>
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<td>0.225</td>
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<td>-31.51*</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(1.60)</td>
<td>(1.29)</td>
<td>(-1.88)</td>
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<td>MD3</td>
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<td>0.333</td>
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<td>-34.03*</td>
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<tr>
<td>TM2</td>
<td>-0.0860</td>
<td>-0.0860</td>
<td>-12.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.60)</td>
<td>(-0.60)</td>
<td>(-1.19)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>0.773***</td>
<td>0.773***</td>
<td>0.912***</td>
<td>5.738</td>
<td>5.738</td>
<td>8.067</td>
</tr>
<tr>
<td></td>
<td>(11.85)</td>
<td>(12.02)</td>
<td>(9.14)</td>
<td>(1.13)</td>
<td>(1.14)</td>
<td>(1.02)</td>
</tr>
</tbody>
</table>

N = 95

* p<0.05, ** p<0.01, *** p<0.001

Figure 7: Results Summary
These results were used to generate two probabilistic equations, shown below.

\[
\ln \left( \frac{P(\text{overdiagnosis})}{P(\text{no error})} \right) = 1.23 \text{ MD} - 1.38 \text{ MD1} - 1.06 \text{ MD2} - 16.25 \text{ MD3} + 1.82 \text{ TM1} + 0.77 \text{ TM2} - 2.36
\]

\[
\ln \left( \frac{P(\text{underdiagnosis})}{P(\text{no error})} \right) = 17.56 \text{ MD} - 17.60 \text{ MD1} - 18.58 \text{ MD2} - 18.81 \text{ MD3} - 0.66 \text{ TM1} - 16.34 \text{ TM2} - 19.22
\]

This analysis showed that physicians tend to be less likely to overdiagnose patients. The difference between nurse practitioners and physicians in terms of underdiagnosing was shown to be insignificant.

Both the multinomial logistic regression (Figure 8) and the logit model (Appendix C) were completed, because though the results of both should theoretically provide the same
probability values, this is not always the case. Table 8 shows some of the predicted probabilities for specific providers, given their levels of clinical and telemedicine experience, providing a diagnosis matching the original diagnosis. As can be seen, the values predicted by each model are generally very similar, though they do differ slightly in each case. These results are also summarized in the scatter plot below (Appendix E).

<table>
<thead>
<tr>
<th>Logit</th>
<th>Mutinomial Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.683936</td>
<td>0.661892</td>
</tr>
<tr>
<td>0.566064</td>
<td>0.588186</td>
</tr>
<tr>
<td>0.9</td>
<td>0.899986</td>
</tr>
<tr>
<td>0.666667</td>
<td>0.666704</td>
</tr>
<tr>
<td>0.631579</td>
<td>0.631629</td>
</tr>
<tr>
<td>0.901901</td>
<td>0.913644</td>
</tr>
<tr>
<td>0.847149</td>
<td>0.829501</td>
</tr>
<tr>
<td>0.631579</td>
<td>0.631629</td>
</tr>
<tr>
<td>0.901901</td>
<td>0.913644</td>
</tr>
</tbody>
</table>

**Table 8: Multinomial Logistic Regression and Logit Comparison**

**Conclusion**

The results of this thesis show that though nurse practitioners do not provide an equivalent quality of care in terms of diagnosis agreement and may be less cost effective when compared to physicians, these differences are small. In a field where patients are often overdiagnosed in an effort to meet parents’ needs, these differences could easily be outweighed by cost savings associated with lower nurse practitioner salaries. With the high frequency of ear infections in children, even small savings per visit could lead to a significant decrease in total costs. Thus further investigation into the total cost of nurse practitioners should be pursued.
Acknowledgements

I would like to thank my advisor Professor Christopher Maxwell for all of his help throughout the process of writing this thesis. I would also like to thank his brother Nick Maxwell for his help in determining prescription and visit costs. Finally, I would like to thank Dr. Kenneth McConnochie and Dr. Eric Biondi for their continued support and for sharing the survey data used in this analysis.

References


Raedle, Joe. “As Primary Care Shortage Looms, Doctors Cut Work Hours.” USA Today, 26 Feb 2010.


Appendices

Appendix A
Re: Study of Telemedicine for Tympanic Membrane Assessment (TM for TMs Study)

We are writing to request your participation in a study of inter-observer reliability in the diagnosis of acute otitis media (AOM) and otitis media with effusion (OME) using telemedicine technology. This relatively new set of medical tools has the potential to be very valuable, increasing accessibility, decreasing costs, and possibly decreasing the rate of unnecessary antibiotic use among children. As with any new diagnostic tool, however, potential drawbacks should be carefully studied.

The TM for TMs Study is designed to assess the hypothesis that OME and AOM diagnoses made through telemedicine are at least as reliable as through in-person visits. This research is a logical next step in following up our earlier research findings on the relative reliability of assessment via telemedicine (McConnochie KM, et al. Differences in diagnosis and treatment using telemedicine versus in-person evaluation of acute illness. Amb Peds, 2006;6:187-195).

Participation in this study includes completion of a 20 minute online course that will introduce you to tympanic membrane ™ images as generated by telemedicine cameras. These images often provide more detail than a quick peek through the usual hand-held otoscope, but clinicians may be unfamiliar with the level of detail these images provide. Consequently, we believe this course will not only be beneficial to study participants but also to clinicians at all levels.

Participants are asked assess 30 randomly selected images online. We expect this assessment will take approximately 15 minutes.

We would greatly appreciate your participation in this study. We expect that study findings will further explicate the value of telemedicine and ultimately contribute to a reduction in the serious problem of unnecessary antibiotic use. We also hope you will find participation informative. Finally, should you choose to participate, we will be pleased to offer a $10 Amazon gift card as a token of our appreciation.

Those willing to participate can access the online program through Blackboard in the University of Rochester Intranet. Please e-mail Margaret_Connolly@urmc.rochester.edu to receive your unique assessment password.
Thank you for your help!

Yours truly,

Margaret Connolly
Eric Biondi
Neil Herendeen
Kenneth McConnochie
Appendix B

Diagnosing Otitis Media via Telemedicine

A Course for Health Care Providers

Eric Bond, MD
Margaret Connolly
Nel Hetarseen, MD
Kenneth McMurray, MD, MPH

Goals

• To introduce the provider to telemedicine

• To display abnormal tympanic membrane attributes as they appear in telemedicine images.

• To exemplify the diagnostic criteria for acute otitis media as rendered by this technology.

Introduction to Telemedicine

• Access

• Patient centered care

Telemedicine for Tympanic Membranes

Telemedicine assistant (technician) using a specially designed camera to image the tympanic membrane.

Review of a Normal Ear Drum

Important attributes of a normal tympanic membrane

• Malleus
• Short process of malleus
• Cone of light
• Umba
• Margin between drum and ear canal
• Blood vessels
• Translucency
• Color

Common Problems with Ear Images

<table>
<thead>
<tr>
<th>Normal TFI, diagnostic quality</th>
<th>Same TFI, sub-standard quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margin between ear drum and ear canal is fuzzy</td>
<td></td>
</tr>
<tr>
<td>Malleus cannot be clearly identified</td>
<td></td>
</tr>
<tr>
<td>No fine detail is apparent (e.g., dilated blood vessels)</td>
<td></td>
</tr>
<tr>
<td>Cone of light is visible not as a distinct cone with clear directionality but only as a blurry bright patch</td>
<td></td>
</tr>
</tbody>
</table>

Left Ear Drums

Diagnosis of Acute Otitis Media (AOM)

How do I know it when I see it?

A diagnosis of AOM requires:

1. Recent onset of symptoms and signs
2. Signs or symptoms of middle-ear inflammation, and
3. Middle-ear effusion (MEE)
The presence of MEE

Indicated by any of the following:

a. Bulging of the tympanic membrane
b. Limited or absent mobility of the tympanic membrane
c. Air-fluid level behind the tympanic membrane
d. Otorrhea

Middle-ear inflammation:

Sign: Distinct erythema of the tympanic membrane
or
Symptom: Distinct otalgia (discomfort clearly referable to the ear that results in interference with, or precludes, normal activity or sleep)

Diagnostic Features

- Translucent
- Mostly colorless
- Concave
- Short process of malleus
- Unibo (approximate bone)

- Opaque
- Red
- Bulging - Linear crease where TM is tethered to unibo

Infected TMs

Left AOM:
- Opaque
- Mostly brown with red patches in areas vessels are more dilated
- Bulging

- Short process of malleus
- Unibo

Infected TMs

Left AOM:
- No, this is not a uterine infection.
- Rotated counterclockwise
- Opaque
- White and red
- Bulging

- Bulging so extreme that almost no feature remains to indicate where the short process of the malleus lies.

Infected TMs

Infected left TM with bulla

AOM:
Broad range of clinical appearance
**AOM continued:**

**Broad range of clinical appearance**

- Various images showing different appearances of AOM.

**OME continued**

- Additional images showing OME.

**Neither AOM nor OME**

- Images of neither AOM nor OME.

**Otitis Media with Effusion (OME)**

- Images of OME with effusion.

**Summary of Diagnostic Criteria**

- Diagnostic criteria for OME with images of typical findings.

**Think about it ...**

- Question about the diagnosis of AOM vs. OME.

**Management of Acute Otitis Media:**

**Should an antibiotic be prescribed?**

- Consider:
  - Over-diagnosis and over-treatment are prevalent.
  - Over-treatment is a serious medical error in the aggregate.
  - Modest benefits of antibiotics: Need to treat 9 children or more for 1 child to benefit. [Cohen TR, et al. JAMA 2010;304:2161-2169]

**Management of Acute Otitis Media - Key Definitions:**

- Certain diagnoses: (1) Recent onset, (2) Signs or symptoms of middle-ear inflammation, (3) Middle ear effusion
- Severe illness: Fever > 39°C at any time in past 24 hr or moderate to severe otalgia
- Careful observation: follow-up ensured so that antibiotics can be started if symptoms persist or worsen, parent enabled to provide pain control
Management of Acute Otitis Media: Antibiotic vs. observation when first seen

Appendix C

.logit Agreement MD MD1 MD2 MD3 TM1 TM2 TM3

Note: MD3 ! = 0 predicts success perfectly
MD3 dropped and 7 obs not used

Note: TM3 omitted because of collinearity
Iteration 0:  log likelihood =  -50.5541
Iteration 1:  log likelihood =  -46.904718
Iteration 2:  log likelihood =  -46.768032
Iteration 3:  log likelihood =  -46.767777
Iteration 4:  log likelihood =  -46.767777

Logistic regression

| Agreement | Coef.     | Std. Err. | z      | P>|z|   | [95% Conf. Interval] |
|-----------|-----------|-----------|--------|-------|---------------------|
| MD        | -1.446603 | .8080742  | -1.79  | 0.073 | -3.0304             |
| MD1       | 1.600754  | 1.062626  | 1.51   | 0.132 | -.4819549           |
| MD2       | 1.425304  | 1.249558  | 1.14   | 0.254 | -1.023784           |
| MD3       | 0         | (omitted) |        |       |                     |
| TM1       | -1.679528 | .8731554  | -1.92  | 0.054 | -3.390881           |
| TM2       | -.5061113 | .796756   | -0.64  | 0.525 | -2.067724           |
| TM3       | 0         | (omitted) |        |       |                     |
| _cons     | 2.218524  | .7322635  | 3.03   | 0.002 | .7833139            |

Number of obs =  88
LR chi2(5) =  7.57
Prob > chi2 =  0.1814
Pseudo R2 =  0.0749

Log likelihood =  -46.767777
Appendix D

```
 . probit Agreement MD MD1 MD2 MD3 TM1 TM2 TM3

 note: MD3 != 0 predicts success perfectly
      MD3 dropped and 7 obs not used

 note: TM3 omitted because of collinearity
 Iteration 0:  log likelihood =  -50.5541
 Iteration 1:  log likelihood =  -46.681972
 Iteration 2:  log likelihood =  -46.634945
 Iteration 3:  log likelihood =  -46.63494

 Probit regression
 Number of obs  =  88
 LR chi2(5)     =  7.84
 Prob > chi2    =  0.1654
 Log likelihood =  -46.63494

           Coef.  Std. Err.      z    P>|z|     [95% Conf. Interval]
------------- ------------- ------------- ------- -------- ------------------------
  Agreement
    MD      -.8691207   .4617512    -1.88   0.060    -1.774136    .035895
    MD1      .9638099   .6266929     1.54   0.124    -.2644858    2.192105
    MD2      .777578    .6677817     1.16   0.244    -.531257    2.086406
    MD3  (omitted)
    TM1     -1.037656   .5147549    -2.01   0.044    -2.045957   -.0281581
    TM2    -.376045    .4618063    -0.81   0.415     -.2181169    .5290787
    TM3  (omitted)
    _cons    1.373094   .4228779     3.25   0.001     .5442689    2.201922
```

Appendix E

![Multinomial Logistic Regression Probability Predictions](image)