Current and Projected Workforce Requirements for Care of the Critically Ill and Patients With Pulmonary Disease: Can We Meet the Requirements of an Aging Population?

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Current and Projected Workforce Requirements for Care of the Critically Ill and Patients With Pulmonary Disease
Can We Meet the Requirements of an Aging Population?

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MEETING THE HEALTH CARE needs of the American people in the coming decades requires accurate forecasts of likely requirements, not only in terms of dollars, but also in terms of staffing and facilities. Unfortunately, such forecasts are difficult because many factors influence health care delivery. One factor likely to increase demand for services is the aging of the US population. During the next 30 years, Medicare enrollment will grow by more than 50%. Because the elderly consume considerable health care resources, demand for medical services is expected to outpace other indices of the economy.

This increased demand might be offset by other factors, such as the growth of managed care. It is argued that physicians create part of the demand for their services. One influential study found managed care plans, by carefully screening physician services, lowered demand for specialist care. Because of anticipated growth in managed care, the Council on Graduate Medical Education predicted specialists would now be oversupplied. Concern over such potential changes in physician requirements generated other forecasts of the physician labor market in the 1990s. Not all studies reached the same conclusion and some
found little evidence to suggest a significant surplus of specialists in the near future.\textsuperscript{10,11} This controversy stems from different assumptions about future health care\textsuperscript{12} and has stimulated several physician groups to conduct further studies.\textsuperscript{13-16}

Two of the largest areas in medicine are the care of the critically ill and the management of pulmonary disease. These areas are likely to be profoundly influenced by an increase in the elderly population. Therefore, the American College of Chest Physicians, the American Thoracic Society, and the Society of Critical Care Medicine formed the Committee on Manpower for Pulmonary and Critical Care Societies (COMPACCS). The goal of this committee was to determine current patterns of care for the critically ill and patients with pulmonary disease, anticipate how demand for care might change in the future, and project the supply based on the current workforce and training. Specifically, we wanted to test 2 competing hypotheses: first, that changes in US health care will lead to an oversupply of specialists and, second, that changes in the demography of the population will lead to an undersupply.

**METHODS**

We used population, patient, hospital, and clinician data to determine national estimates of the use of adult critical care and pulmonary services in the United States, the proportion of these services provided by specialists, and the number and practice characteristics of the current specialist workforce. From these data, we constructed models to describe the current and future demand for and supply of critical care specialists (intensivists) and pulmonary specialists (pulmonologists). We modeled critical care and pulmonary medicine separately. Our models were based on relationships between the size and growth of the US population; the age- and disease-specific use of intensive care units (ICUs); the age-specific prevalence of pulmonary disease; and the training, retirement, work hours, and practice patterns of intensivists and pulmonologists. We tested the robustness of our model design and results in sensitivity analyses, which explored the effect of alternative scenarios of disease prevalence, physician work effort, number of new specialists trained, and health care organization. Our methods followed the general approaches for modeling current and future workforce supply and requirements described elsewhere.\textsuperscript{17,18} The full COMPACCS report is available at http://www.abtassociates.com/reports/health-care/chest2.pdf and a copy of the physician supply and demand forecast model can be downloaded at http://www.abtassociates.com/reports/health-care-download.html.

**Population and Patient Data**

We derived current and projected age-specific population estimates from the US Census (available at: http:\/\slashwww.census.gov). We determined the number of ICU days by disease and by age from the 1995 Healthcare Financing Administration Medical Provider Analysis and Review file for those aged 65 years and older and the 1995 New Jersey Hospital Reporting System hospital reporting file for those aged 18 to 64 years. We used age-specific population-based ICU use rates to generate national estimates. We drew similar data on inpatient days for patients hospitalized with pulmonary conditions from the fifth release of the nationwide inpatient sample of the Healthcare Cost and Utilization Project-3\textsuperscript{19} and generated national totals using weights provided on the file. We determined the number of ambulatory visits for pulmonary conditions from the 1997 enrollee and encounter data from United HealthCare Corp (Minneapolis, Minn), one of the nation’s largest health care insurance companies. United HealthCare represents approximately 2.5 million person-years of care from more than 30 geographically dispersed health plans. We calculated disease- and age-specific use rates to generate national estimates of all pulmonary ambulatory visits and the proportion provided by pulmonologists. We gathered similar data from the 1994 Washington state Medicare Part B claims data, which had been linked previously to enroll, hospital, and clinician data to generate population-based use rates.\textsuperscript{20}

**Physician, Hospital, and Health Care Organizational Data**

To document specialist practice patterns, we surveyed 10% of a stratified random sample of all physicians (n = 10,244) in the 1996 American Medical Association Physician Masterfile who were currently practicing in the United States with a primary or secondary specialty of critical care or pulmonary medicine.\textsuperscript{21} The sampling frame was stratified by age, sex, specialty, and region—classifying region both by population size—using the Beale coding system,\textsuperscript{22,23} and by managed care penetration, using the 1997 University HealthSystem Consortium classification (University HealthSystem Consortium Member Market Classification, Oak Brook, Ill). We altered sampling probabilities to ensure that particular smaller subgroups (eg, women, surgeons, and rural physicians) were adequately represented.

To understand physician practice and organization within ICUs, we surveyed a stratified random sample of hospital-appointed ICU directors at all adult noncardiac ICUs in the United States. We selected all acute care hospitals (n = 4,440) in the United States with 1 or more ICUs from the 1996 SMG Hospital Market database (SMG Marketing Group, Chicago, Ill). From this list we produced a sampling frame that was stratified by hospital size and region and classified as above. We oversampled larger hospitals because they have a greater proportion of ICUs, including specialty ICUs, such as trauma or burn units. We telephoned each hospital in the sample to determine the number of ICUs and the number of hospital-appointed directors of each unit. We then selected units within each hospital (n = 1173), using a ran-
dom stratified sampling technique to ensure a representative sample of general (medical/surgical), medical, surgical, and specialty ICUs.

We asked ICU directors to specify how care was provided for each patient in their ICU on the day the survey was completed. We used 4 care models: a full-time intensivist model, in which all or most of a patient's care is directed by an intensivist (an intensivist was defined as an attending physician who, by training or experience, provides care for the critically ill in a role broader than that provided by a consultant specialist); a consultant intensivist model, in which an intensivist consults for another physician to coordinate or assist in critical care but does not have primary responsibility; a multiple consultant model, in which multiple specialists are involved (in such instances, a pulmonologist or intensivist may be consulted for ventilator management but no one is designated as the consultant intensivist); and a single physician model, in which the primary physician provides all ICU care.

Response rates were 42.1% (n=421) and 33.5% (n=393) for the physician and ICU director surveys. Respondents and nonrespondents to the physician survey were generally similar in age and base specialty training and near-identical regional distribution and professional activities. However, respondents were more likely to be men (86% vs 79%; P<.01), more likely to be surgeons (14% vs 10%; P<.01), and less likely to be internists (14% vs 19%; P<.01). There were no significant differences in response rates by region or subgroup in the ICU director survey. We generated nationally representative estimates from the surveys, adjusting for both sampling probabilities and response rates.

Determining the Current and Future Demand for Specialist Care
To determine demand for intensivists, we calculated ratios of total annual hours provided by intensivists in adult, noncardiac ICUs (estimated from the Physician Masterfile and survey) to total numbers of adult, noncardiac ICU patient days per annum (estimated from Medical Provider Analysis and Review file and state patient data). We estimated separate ratios for each combination of managed care penetration level, disease category, and patient age group. We determined total demand by summing the products of each combination’s ratio and number of ICU patient days.

We determined demand for pulmonologists similarly, constructing separate models for inpatient and ambulatory pulmonary services. For inpatient care, we calculated the ratio of total hours (estimated from the Physician Masterfile and survey) reported by pulmonologists in direct, non-ICU, inpatient care of pulmonary disease to the number of non-ICU inpatient days during hospital admissions for pulmonary conditions (estimated from Healthcare Cost and Utilization Project-3 nationwide inpatient sample). We assumed the proportion of cases treated by pulmonologists and the average time per case were equal within disease and age groups. For ambulatory care, we calculated the ratio of hours spent by pulmonologists providing pulmonary (as opposed to general medical or other) ambulatory care (estimated from the Physician Masterfile and survey) to the total number of ambulatory visits for pulmonary conditions (estimated from the United HealthCare data). We estimated the number of ambulatory visits and the proportion involving pulmonologists both by disease and age group, assuming the time per visit was equal across disease and age group.

Under the base case, we modeled future demand as a function of the US census estimates of the changing age structure multiplied by current age- and disease-specific use rates.

Determining the Current and Future Supply of Specialist Care
We defined the supply model as the product of the number of specialists multiplied by the average annual clinical hours spent by specialists in intensive care, inpatient pulmonary care, and ambulatory pulmonary care. We used weighted least-squares regression to estimate the conditional distribution of total hours worked, total clinical hours, and clinical hours by setting. Model covariates were physician age, sex, specialty, faculty status, and degree of managed care penetration in the physician’s local market area, with interaction terms for age and sex and for age and specialty. We tested alternative specifications of the regression models using different measures of managed care penetration and sets of interaction terms. In each case, the regression equation that we used for model construction was the one attaining the highest value of the Akaike information criterion.

Under the base case, we modeled future supply assuming changes in annual hours would be due to the changing age structure of the specialist population, the number of physicians graduating from fellowship programs, and the number of physicians retiring from practice. We assumed the number of physicians entering specialist practice matched the number of graduates from all critical care and pulmonary training programs. We obtained the current number of graduates from published data. Based on recent reductions in the number of graduates and external funding restrictions on training programs, we assumed the number of graduates from pulmonary, pulmonary/critical care, and internal medicine/critical care programs would decrease by another 10% in the next 10 years. We assumed the proportion of female graduates would increase to 40% in the next 10 years. We modeled retirement based on the physician survey responses for each clinical domain and assuming a Weibull density.

Sensitivity Analyses
We tested the sensitivity of our model design and base-case estimate to (1) the effect of age-independent changes in the incidence, prevalence, and management of pulmonary diseases and those diseases commonly managed in the ICU; (2) the spread and penetration of man-
aged care throughout the country; (3) retirement patterns; (4) the distribution of clinical hours between different clinical and nonclinical activities; and (5) changes in the number of specialty trainees. We determined the boundaries for the sensitivity analyses (including the size and timing of any change in the base model variables) prior to seeing the forecast model. Boundaries were based on the stochastic error distributions of variables, literature review, additional survey data, and the expert opinion of the COMPACCS Committee. When considering ranges, we assumed no major changes in the reimbursement for specialist services.

RESULTS

Current Demand for Adult Critical Care Services

More than half of all ICU days (55.8%) were incurred by patients older than 65 years with the number of days per year per 1000 person-years varying from 37.3 for adults younger than 65 years to 178.4, 244.9, and 230.9 for those aged 65 to 74, 75 to 84, and older than 85 years, respectively. Half of the patients (45.6%) were managed under the multiple consultant model with 23.1% managed under the full-time intensivist model, 13.7% under the consultant intensivist model, 14.2% under the single physician model, and 3.4% under other arrangements. Intensivists provided care to at least 1 patient in 59.1% of all ICUs and provided that care as a full-time intensivist in 29% of ICUs. Intensivists were significantly more likely to be involved in the care of patients with respiratory insufficiency, multiple organ failure and sepsis, and less likely to be involved in the care of postoperative patients and patients with burns.

In regression analysis, intensivists were more likely to provide care in medical ICUs (odds ratio [OR], 1.4; \( P = .006 \)), ICUs in larger hospitals (ORs, 4.3 \( P = .01 \)) and 3.4 \( P = .01 \) for hospitals with 301-500 and >500 beds), and ICUs with a high proportion of patients covered by managed care (OR, 1.6 for ICUs with >30% managed care case-mix \( P = .01 \)).

Current Demand for Adult Pulmonary Services

Two thirds (66.8%) of all inpatient pulmonary days were incurred by patients older than 65 years with the number of days per year per 1000 person-years increasing from 38.3 for adults younger than 65 years to 261.7, 443.1, and 634.1 for those aged 65 to 74, 75 to 84, and older than 85 years, respectively. Pneumonia, chronic obstructive pulmonary disease, and respiratory failure accounted for 80.5% of all days. Pulmonologists were significantly more likely to care for patients with chronic obstructive pulmonary disease, asthma, and respiratory failure and less likely to care for patients with pneumonia.

Unlike inpatient care, most pulmonary ambulatory visits were incurred by patients younger than 65 years (80.1% and 67.8% of all pulmonary disease-related visits to generalists and to pulmonologists). The number of visits to pulmonologists per 1000 person-years increased from 23.9 for patients younger than 65 years to 84.9, 103.1, and 67.7 for those aged 65 to 74, 75 to 84, and older than 85 years, respectively. With the exception of interstitial lung disease (50.3%) and respiratory failure (50.4%), pulmonologists generally provided less than 10% of all ambulatory pulmonary care. In the Washington state Medicare population, the use of pulmonologists was 23.7% and 28.5% higher in those aged 65 to 74 and 75 to 84 years (compared with the United Healthcare data) but similar (66.5 visits per 1000 person-years) in those older than 85 years.

Characteristics of Current Specialist Workforce

Characteristics of current intensivists and pulmonologists are outlined in Table 1. Most are trained in pulmonary and critical care medicine. The remainder have base specialty training in internal medicine, anesthesiology, or surgery and are younger, more likely to be university-affiliated, and include a higher proportion of women. Most are certified in their base specialty but only half are certified in critical care, although this varies substantially across subspecialties. Only a small proportion of the workforce is salaried, and a smaller proportion still are employed by managed care organizations.

Specialists worked 61 hours per week for 48 weeks (2933 hours per year), with 78% (2284 hours) of time spent in clinical activities. They spent 26.1% of their clinical time in the ICU, although this ranged from 23.4% for those with pulmonary training to 46.2% for nonpulmonary internal medicine-based intensivists. Pulmonologists spent 67.1% of their non-ICU clinical time providing pulmonary services. In regression analyses,

Table 1. Characteristics of Current Critical Care and Pulmonary Specialist Workforce

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pulmonary*</th>
<th>Internal Medicine†</th>
<th>Anesthesiology</th>
<th>Surgery</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%) of total</td>
<td>8080 (79.9)</td>
<td>1220 (11.9)</td>
<td>620 (6.1)</td>
<td>324 (3.2)</td>
<td>10 244</td>
</tr>
<tr>
<td>Age, mean, y</td>
<td>48.9</td>
<td>42.1</td>
<td>44.8</td>
<td>43.3</td>
<td>47.7</td>
</tr>
<tr>
<td>Type of practice group, %</td>
<td>University-affiliated</td>
<td>13.4</td>
<td>13.9</td>
<td>35.4</td>
<td>46.0</td>
</tr>
<tr>
<td>Hospital or health maintenance organization staff</td>
<td>9.4</td>
<td>5.4</td>
<td>8.0</td>
<td>11.5</td>
<td>9.0</td>
</tr>
</tbody>
</table>

*Includes physicians whose only specialty practice was pulmonary medicine and physicians who practiced both pulmonary and critical care medicine.
†Includes internal medicine physicians who practice critical care but do not practice pulmonary medicine.
‡Includes Veterans Affairs staff.

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women worked 307 fewer total annual hours (P = .01) and 379 fewer clinical hours (P < .01) than men. Specialists in areas with greater than 25% managed care penetration worked 344 more total hours (P < .01), 202 more clinical hours (P = .01), and 268 more pulmonary hours (P < .01) than others. Older physicians and full-time faculty also worked fewer clinical hours.

In 1996, there were 354 graduates from pulmonary and pulmonary/critical care medicine programs, 110 graduates from internal medicine critical care programs, 67 graduates from surgical critical care programs, and 63 graduates from anesthesiology critical care programs.

Forecasting Future Intensivist Supply and Demand

The numbers of intensivists demanded and supplied as projected by the base model and sensitivity analysis are shown in the Figure and in Table 2. Intensivist hours supplied and demanded remain in rough equilibrium until 2007, both increasing by 10% more than their 1997 values. Thereafter, demand grows rapidly while supply remains near constant, yielding a shortfall of intensivist hours equal to 22% of demand by 2020 and 35% by 2030. This discrepancy is due primarily to the increased elderly population as baby boomers age.

In sensitivity analysis, the shortfall widens markedly if there is demand for intensivist care to a greater proportion of ICU patients. Otherwise, most supply and demand variables have only a small effect on the ratio of supply to demand in comparison with the effect of an aging population. Although changes in health care delivery, such as the effect of increased managed care penetration, will affect the balance of supply and demand during the next 10 to 15 years, no variable led to a large reduction in the ever-widening shortfall predicted thereafter.

Forecasting Future Pulmonologist Supply and Demand

The numbers of pulmonologists demanded and supplied as projected by the base model and sensitivity analysis are shown in the Figure and in Table 3. Again, this model shows an increasing demand with time while supply is near constant. The shortfall develops sooner because the current workforce is anticipating retirement at a rate faster than the graduation rate. The shortfall in pulmonologist hours is predicted to be 35% by 2020 and 46% by 2030.

In sensitivity analyses, significant deployment of nonpulmonary clinical time to pulmonary care delays the onset and reduces the magnitude of the shortfall but demand still outstrips supply by 10% in 2020 and 16% in 2030. Again, the finding of a significant discrepancy in supply and demand, driven principally by the aging population, is generally robust to the sensitivity analysis, including the likely effects of managed care.

COMMENT

Our results suggest that the proportion of care provided by specialists in critical care and pulmonary medicine cannot be maintained in the United States for more than 10 years. The prin-
pincipal reason is the increased demand for care as the population ages. We found variation in current practice patterns, including differences associated with health care reform initiatives. However, our sensitivity analyses suggest these initiatives, and other potential changes in supply and demand, will not prevent and may even promote the shortfall.

Reports on Medicare have predicted increased costs and demand for services as the US population ages. Lacking from these reports, however, are details on how to deliver these services. Simultaneously, a common view has emerged that graduate medical training should remain constant or decrease. This has created a public policy paradox. Despite widespread recognition that elderly health care needs will grow, there is no planning for who will actually provide this care.

This situation is the legacy of a decade-long debate whose premise was that the US had an oversupply of physicians in general and of specialists in particular. In 1994, the Council on Graduate Medical Education predicted an increase in demand for generalist physicians and a decrease in demand for specialists. The Council on Graduate Medical Education relied heavily on assumptions of managed care growth and associated efficiencies. Others, using managed care use data, reached similar conclusions. These predictions have proven inaccurate as patient resentment of managed care restrictions and the threat of litigation have prompted managed care companies to liberalize access to specialty care.

Our study differs substantially from most previous workforce models. First, our forecast horizon extends beyond 2010, thereby capturing the major demographic shift toward the elderly. Second, as discussed above, previous studies relied on the flawed assumption that managed care would decrease demand. Our study suggests that, at least for intensivists, managed care may actually increase demand. Third, we treated demand and supply independently. Some models of physician labor markets assumed physician supply drives demand. However, as

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Case</th>
<th>Sensitivity Range</th>
<th>Range of Ratios of Supply to Demand by Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Demand:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease-related§</td>
<td>No change in disease-specific ICU use</td>
<td>110%-90% of current use rates</td>
<td>0.94-1.11</td>
</tr>
<tr>
<td>Age-related§</td>
<td>No change in age-specific ICU use</td>
<td>20% decrease in use by those older than 85 y; 10% decrease in use by those aged 75-85 y</td>
<td>1.01</td>
</tr>
<tr>
<td>Use of intensivists¶</td>
<td>No change (36.8% of ICU patients)</td>
<td>Increase to 66%-100% of all ICU patients</td>
<td>0.61-0.78</td>
</tr>
<tr>
<td>Supply:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women, %</td>
<td>Increase from 19% to 40% of workforce in 10 y</td>
<td>50%-19%</td>
<td>1.02-1.02</td>
</tr>
<tr>
<td>No. of graduates</td>
<td>10% decrease in pulmonary and internal medicine graduates in 10 y</td>
<td>20%-0%</td>
<td>1.01-1.04</td>
</tr>
<tr>
<td>No. of hours worked</td>
<td>No change from current practice patterns</td>
<td>90%-110%</td>
<td>0.94-1.10</td>
</tr>
<tr>
<td>Age at retirement, y</td>
<td>No change from current practice patterns (mean, 60 y)</td>
<td>58-62 y</td>
<td>1.01-1.03</td>
</tr>
<tr>
<td>Managed care effects on demand and supply (range)#</td>
<td>No change in current penetration of US markets (50% of US markets with &gt;25% penetration)</td>
<td>Increase to 80% of US markets with &gt;25% managed care penetration</td>
<td>1.06 (0.98-1.09)</td>
</tr>
</tbody>
</table>

*ICU indicates intensive care unit.
†Demand is used to describe the number of specialists required at a given time point to maintain a national level of care similar to that provided currently.
§The Committee on Manpower for Pulmonary and Critical Care Societies concluded there was no disease for which there was clear evidence of a change in the age-specific prevalence because emerging technologies could both increase or decrease ICU use, and unmeasured health care reforms were unpredictable and therefore recommended varying all ICU use ± 10%.
¶The effect of limiting intensive care at the end of life was modeled as a reduction in ICU use among the elderly.
#Managed care penetration was associated with both an increased use of full-time intensivists (demand) and a greater number of hours spent providing critical care (supply). Results expressed as combined effect (range, demand-only to supply-only effects).

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pointed out by Reinhardt, this assumption has proven overly simplistic, failing to account for much of the variation in physician work patterns. In addition, demand for critical care and pulmonary services is likely to be less discretionary than that for more procedure-driven specialty services. Finally, intensivists and pulmonologists provide only a portion of critical care and pulmonary services. Therefore, while there may be some coupling of demand to supply, such an effect is likely to be weaker than for other physician groups.

We found intensivists currently provide one third of ICU care and, without increased supply, will provide a smaller proportion in the future. It is therefore key to determine the optimal proportion and types of ICU patients who should be treated by intensivists. Our study was not designed to answer this question. However, studies suggest care by intensivists is associated with decreased resource use and improved patient outcomes. Therefore, it is possible that the current proportion of ICU patients managed by intensivists is already less than ideal. For patients with pulmonary disease, there are no studies comparing outcomes for those treated by pulmonologists compared with other physicians.

We explored potential responses to the predicted shortfall of specialist hours. Specialists could dedicate more hours but this would be insufficient to reverse the shortfall and would require financial incentives, contradict trends in specialist work habits, and potentially lead to burnout. Health care reform initiatives are unlikely to affect our predictions. While such initiatives have reduced the length of hospital stays for many conditions, total age-specific use rates have not decreased but actually have grown.41 Furthermore, managed care organizations have shown little ability to reduce resource use by ICU patients.42 Although technologic advances might theoretically reduce need for specialist care, the more usual pattern is for technology to increase demand for care.41,43

We found no epidemiological data to suggest future decline in the incidence of pulmonary diseases or those disorders requiring critical care. These conditions are common complications of many illnesses and are driven by patient demographics. Greater use by the elderly of advanced directives to limit intensive care at the end of life could be encouraged. However, the consequences in our sensitivity analysis were small and other studies suggest that the elderly recover well from critical illness.44,46 Thus, if tacit rationing of health care is to be minimized, we must explore mechanisms to ensure that qualified health care clinicians are available to care for the growing burden of critical care and pulmonary disease.

**Table 3. Pulmonary Forecast Model and Sensitivity Analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base Case</th>
<th>Sensitivity Range*</th>
<th>Range of Ratios of Supply to Demand by Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Base case</td>
<td></td>
<td></td>
<td>0.89</td>
</tr>
<tr>
<td>Demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease-related†</td>
<td>No change in disease-specific use of pulmonologists</td>
<td>110%–90% of current use rates</td>
<td>0.82-0.96</td>
</tr>
<tr>
<td>Age-related</td>
<td>No change in age-specific use of pulmonologists</td>
<td>20% decrease in use by those &gt;85 y; 10% decrease in use by those 75 to 85 y</td>
<td>0.92</td>
</tr>
<tr>
<td>In-patient setting</td>
<td>No change</td>
<td>20% decrease in use</td>
<td>0.96</td>
</tr>
<tr>
<td>Ambulatory setting</td>
<td>No change</td>
<td>20% decrease in use‡</td>
<td>0.96</td>
</tr>
<tr>
<td>Supply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women, %</td>
<td>Increase from 19% to 40% of workforce in 10 y</td>
<td>50%–19%</td>
<td>0.88-0.89</td>
</tr>
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<td>No. of graduates</td>
<td>10% decrease in graduates in 10 y</td>
<td>20%–0%</td>
<td>0.88-0.90</td>
</tr>
<tr>
<td>No. of hours worked</td>
<td>No change from current practice patterns</td>
<td>90%–110%</td>
<td>0.82-0.96</td>
</tr>
<tr>
<td>Age at retirement, y</td>
<td>No change from current practice patterns (median, 60 y)</td>
<td>58–62 y</td>
<td>0.87-0.90</td>
</tr>
<tr>
<td>No. of hours worked in internal medicine</td>
<td>No change from current practice</td>
<td>50% of all internal medicine time reallocated to pulmonary care</td>
<td>1.01</td>
</tr>
<tr>
<td>Managed care effect on supply</td>
<td>No change in current penetration of US markets</td>
<td>Increase to 80% of US markets with &gt;25% managed care penetration</td>
<td>0.92</td>
</tr>
</tbody>
</table>

*The effect of limiting the use of specialist care at the end of life was modeled as a reduction in use among the elderly.
†The Committee on Manpower for Pulmonary and Critical Care Societies concluded that while asthma was increasing and chronic obstructive pulmonary disease was decreasing, there were no other diseases for which there was clear evidence of a change in the age-specific incidence or prevalence. Emerging technologies could both increase or decrease the use of pulmonary services and unmeasured health care reforms were unpredictable but could include selective effects on either the inpatient or ambulatory settings.
‡This decrease is larger than the difference observed in use rates between the Washington state Medicare data and the United Health Care data.
The implications of our study outside the United States are less clear. There is wide international variation in intensivist training and accreditation and in the availability of ICU beds. In some countries, including Australia, New Zealand, and several western European nations, virtually all ICU care is delivered by intensivists while in others there is little formal critical care training. There is little information on international variation in supply and demand for pulmonary services, and we are not aware of forecast models from other countries. However, many nations have aging populations and increasing health care costs and may face similar increases in demand for care. Given that the increased demand of an aging population was the strongest driving force of our forecast model, our findings may generalize to countries with similar demographics, such as many industrialized nations. Indeed, a recent study from the United Kingdom demonstrated that demand for ICU beds has increased in recent years, leading to premature ICU discharges and increased hospital mortality.

Our study has several potential limitations. The American Medical Association Physician Masterfile, while commonly used as a source for the US physician workforce, may not capture all practicing physicians. In some specialties, such as surgery, the number we identified is less than the number who have graduated during the past 10 years. However, our forecast model suggests the number of new graduates, based on well-documented training program records, maintains supply at a near-constant level. If the existing workforce were larger than our estimate, then the projected number of new graduates would not maintain current supply, worsening the projected shortfall.

The use of administrative patient-level data also has potential inaccuracies. We used these data principally to understand the distribution of resource use by disease and by age. Sensitivity analyses suggested our results were generally robust to variation in our initial estimates. In addition, because information on ICU resource use for adults younger than 65 years came from only 1 state, we compared overall age-specific ICU use estimates with 2 other states (data not shown) and found differences of less than 10%. Some ranges in our sensitivity analysis might be considered too low. For example, the effects of managed care that we measured were average effects and particular health care systems may use intensivists in ways more extreme than we found. If such models were to proliferate disproportionately, the managed care effects could be larger. Our model also relies on data from 2 surveys. Although we found minimal differences between respondents and nonrespondents, survey results could still be inaccurate. Indeed, there is potential imprecision and error in all the estimates incorporated in our model. However, we believe our sensitivity analyses suggest our results are generally robust to such errors.

In conclusion, we predict the aging of the US population will create a demand for care that will outpace the future supply of intensivists and pulmonologists. The resulting shortfall is troubling both because the current provision of intensivist care is arguably already low and because the aging population will likely create similar shortfalls in other areas of medicine. These observations contradict the common perception that specialists will be oversupplied in the future and raise concerns regarding the provision of other components of care, such as the supply of other health care workers and of adequate health care facilities. Because potential solutions, such as changes in training and education or development of alternative delivery models, require significant lead time to affect care, we believe prompt attention is necessary. Otherwise, the growing disease burden in the United States will stress an unprepared health system, and, in particular, disadvantage the elderly.

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REFERENCES


11. Hart LG, Wagner E, Pizzada S, Nelson AF, Rosen-