The Pathologist Workforce in the United States

II. An Interactive Modeling Tool for Analyzing Future Qualitative and Quantitative Staffing Demands for Services

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• ***Context.***—**Pathologists are physicians who make diagnoses based on interpretation of tissue and cellular specimens (surgical/cytopathology, molecular/genomic pathology, autopsy), provide medical leadership and consultation for laboratory medicine, and are integral members of their institutions' interdisciplinary patient care teams.**

Objective.—**To develop a dynamic modeling tool to examine how individual factors and practice variables can forecast demand for pathologist services.**

Design.—**Build and test a computer-based software model populated with data from surveys and best estimates about current and new pathologist efforts.**

Results.—**Most pathologists' efforts focus on anatomic (52%), laboratory (14%), and other direct services (8%) for individual patients. Population-focused services (12%) (eg, laboratory medical direction) and other professional responsibilities (14%) (eg, teaching, research, and hospital committees) consume the rest of their time. Modeling scenarios were used to assess the need to increase or decrease efforts related globally to the Affordable Care Act, and specifically, to genomic medicine, laboratory consolidation, laboratory medical direction, and new areas where pathologists' expertise can add value.**

Conclusions.—**Our modeling tool allows pathologists, educators, and policy experts to assess how various factors may affect demand for pathologists' services. These factors include an aging population, advances in biomedical technology, and changing roles in capitated, value-based, and team-based medical care systems. In the future, pathologists will likely have to assume new roles, develop new expertise, and become more efficient in practicing medicine to accommodate new value-based delivery models.**

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Pathologists are physicians who make diagnoses based on interpretation of tissue and cellular specimens (anatomic pathology [AP]), provide medical direction to clinical laboratories (laboratory medicine [LM], commonly called *clinical pathology* [CP]), and support the health care teams of institutions and health systems (see Table 1 for acronyms). The services of pathologists and their laboratory teams are crucial in any high-quality health care system.

Although the technical component of pathology and laboratory testing consumes only a small fraction of the average medical system's budget (2.5% for all health care, but about 5.1% in the hospital),[1] the results have a decisive role in patient care because that testing informs medical decisions on management and treatment. Used optimally, the laboratory is believed capable of saving 30% of all potentially avoidable costs in the PROMETHEUS Payment categories listed in a commercially insured population model.[2] Poor-quality, incorrect, or unnecessary testing is wasteful and potentially harmful.[3]

The laboratory as we know it today, both in the United States and abroad, is generally short staffed.[4–6] Too few technologists and technicians are available, which has

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Table 1. Acronyms	
AABB	Formerly known as American Association of Blood Banks
AAMC	American Association of Medical Colleges
ACA	(Patient Protection and) Affordable Care Act
ACGME	Accreditation Council for Graduate Medical Education
ACO	Accountable Care Organization
AOA	American Osteopathic Association
AP	Anatomic Pathology
ASHI	American Society for Histocompatibility and Immunogenetics
C4C	Case for Change (College of American Pathologists)
CAGR	Compound Annual Growth Rate
CAP	College of American Pathologists
CBCs	Complete blood counts
CLIA	Clinical Laboratory Improvement Amendments Act (of 1988)
CMS	Centers for Medicare and Medicaid Services
COLA	Commission on Office Laboratory Accreditation
CP	Clinical Pathology
EHR	Electronic health record
FDA	US Food and Drug Administration
FNA	(Image-guided) Fine-needle aspiration
FTE	Full-time equivalent
GA	Genomic analysis
GAO	US Government Accountability Office
GI	Gastrointestinal pathology
GU	Genitourinary pathology
HLA	Human leukocyte antigen
HMO	Health Maintenance Organization
HPV	Human papillomavirus
IVM	In vivo microscopy
LAP	(CAP) Laboratory Accreditation Program
LIP	(CAP) Laboratory Improvement Program
LM	Laboratory medicine (also called clinical pathology)
LMD	Laboratory medical directorship
MA	Medical administration
NAMCS	National Ambulatory Medical Care Survey
NHAMCS	National Hospital Ambulatory Medical Care Survey
PA	Pathologists' assistant
PAP	Papanicolaou test
PCS	(CAP) Practice Characteristics Survey
POC	Point-of-care
POL	Physician office laboratory
POS	Point of service
PPACA	Patient Protection and Affordable Care Act
PPO	Preferred provider organization
RVU	Relative value units
SEER	Surveillance, Epidemiology, and End Results program
TJC	The Joint Commission, formerly JCAHO (Joint Commission on Accreditation of Healthcare Organizations)

created significant shortages, although slightly fewer shortages in 2012–2013 than in 2010.[6]

In a previous study,[7] we examined the projected *supply* of pathologists in the United States and concluded that every year, throughout the next 2 decades, more pathologists will leave than will enter the field and that by 2030, the number of practicing pathologists will drop from about 17 500 full-time equivalent (FTE) employees in 2010 to about 14 000 FTE employees. The per capita pathologist ratio will have declined from 5.7 to 3.7 per 100 000 people.

In this follow-up study, we examined the projected *demand* for pathologists. We used a flexible, interactive modeling tool, where assumptions could be tested at will, and multiple scenarios could be developed. We reviewed (1) the medical services that pathologists provide and their service settings; (2) new needs, especially the drivers of new demand; and (3) new science and technologies in prevailing trends and in new professional roles capitalizing on pathologists' dual expertise as physicians and providers of laboratory-based health care. The tool helps address the concern the Institute of Medicine raised recently that "the nation is not training the right specialty mix of physicians to meet society's needs."[8(p25)]

Our model can forecast and quantify trends, indicating high, medium, and low impact on demand, and can test potential gaps in supply in many service areas. Consistent with the caveat in *Complexities of Physician Supply and Demand: Projections Through 2025*,[9] we did not intend to predict the future but to develop projections by asking what would happen under certain conditions that might well change, including uncertainties in the changing health care environment.

MATERIALS AND METHODS

Study Organization

This study was part of the multiyear initiative, the "Case-for-Change" (C4C), launched by the College of American Pathologists (CAP).[10] The initiative had 4 workgroups: (1) Workforce Supply and Demand, (2) Existing and New Services, (3) Practice and Economic Models, and (4) Emerging Technologies. The Transformation Program Office Steering Committee provided direction and oversight. More than 80 pathologists, representing diverse clinical environments and/or expertise, were members of the steering committee. For 18 months, they collaborated electronically and in face-to-face meetings, collected public and proprietary data, and surveyed CAP members and outside sources.

Development of the Pathologist-Demand Model

The study proceeded in 3 phases:

1. A literature search about areas of potential demand or factors influencing demand, scoring the availability and accuracy of data as high, medium, low, or unavailable (Supplemental Table 1; see supplemental material file at www.archivesofpathology.org in the November 2015 table of contents).
2. A C4C survey (2010) of CAP members, clinicians, and other health care leaders (eg, hospital and insurance executives); nonmedical health-engaged Americans; and policy-makers in the Washington, DC, area, supplemented by the CAP *Practice Characteristics Survey Report* of CAP members from 2011 and 2014 (PCS-11[11] and specific, limited data from the current PCS-14[12]) and deidentified or anonymized internal CAP data from the Laboratory Improvement Programs and Laboratory Accreditation Program.
3. Development of an interactive system based on algebraic formulations to model demand for pathologist services.

Baseline Demand

Taxonomy.—To stratify demand, we defined 3 broad service areas that pathologists typically provide (Figure 1; Table 2).

One Patient at a Time.—These are patient-centric services that require analysis of information and specimens related to specific patients, including:

1. Anatomic pathology: examination of tissue and cells. This broad category includes the areas generally known as surgical pathology, cytopathology, and autopsy pathology.
2. Laboratory medicine/clinical pathology: The work of this group entails analysis of bodily fluids, including some tissues, and includes transfusion medicine (blood bank and apheresis work)

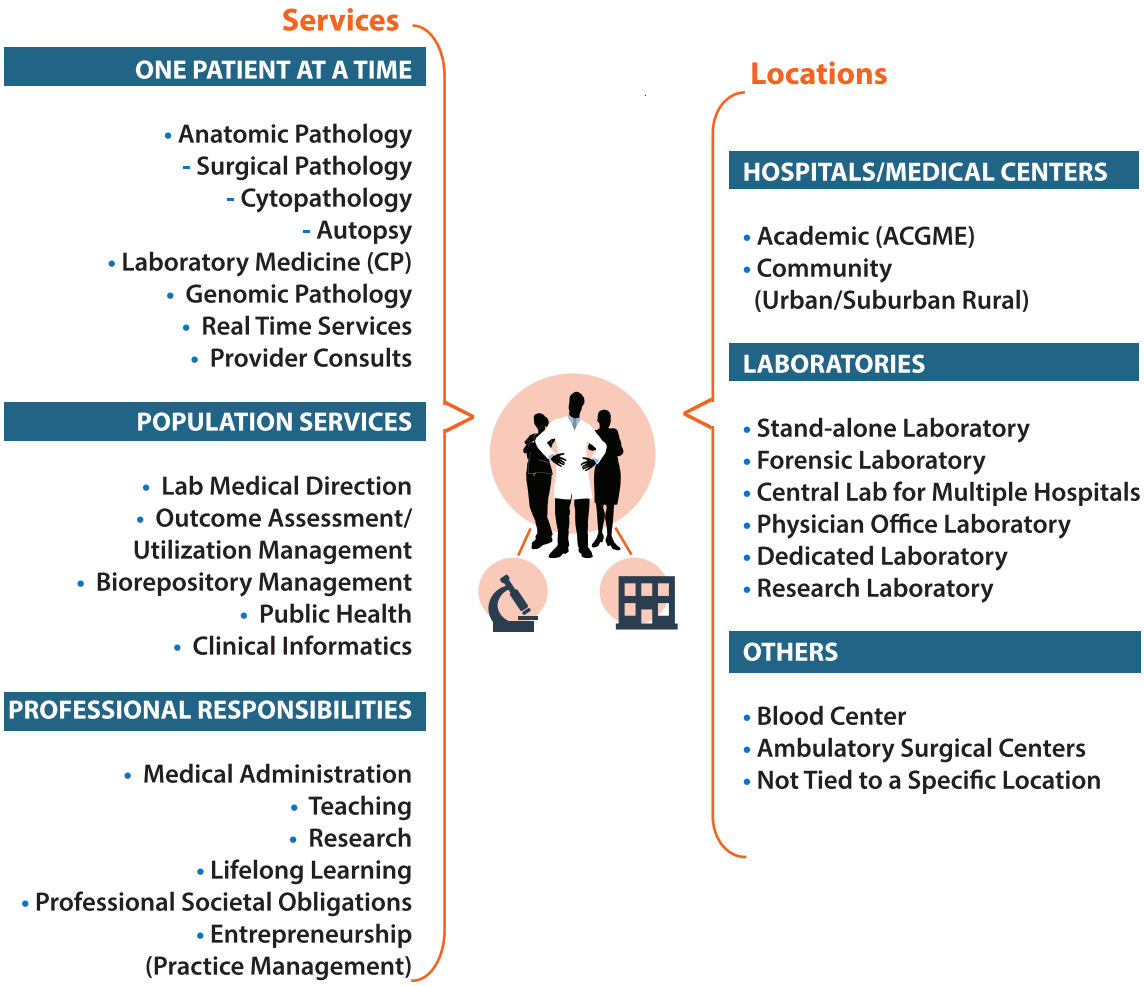


Figure 1. *Taxonomy of pathologist activities by service and location. Abbreviations: ACGME, Accreditation Council for Graduate Medical Education; CP, clinical pathology.*

(note: AP and LM increasingly overlap, especially in molecular pathology, cytogenetics, and hematopathology).

3. Real-time services: This category includes care and consultation provided for individual patients.
4. Provider consults: This grouping entails consultation with other health care providers.

Population Services.—These services are provided to the overall patient community, rather than to individual patients, and include medical oversight of clinical laboratories, management of biorepositories, public health functions and assessment of health outcomes, and point-of-care programs that oversee management of outpatients with chronic diseases. Also in this category is laboratory medical directorship (LMD), which includes oversight of clinical laboratories, including maintaining and ensuring quality standards, certifications, and regulatory compliance.

Professional Responsibilities.—These services relate, directly or indirectly, to pathology as a discipline, including medical administration, teaching, maintenance of competence and certification, research, practice management, and business (entrepreneurship). Medical administration includes professional activities associated with institutional and nonlaboratory operations, such as serving on hospital committees, assisting administrators with strategic planning, and managing personnel.

Location of Services.—We stratified services by the type of facilities in which pathologists provide their services (location). These facilities include academic, urban, community, and rural hospitals; medical laboratories of various types; blood centers; ambulatory surgical centers; and industrial and other facilities.[13]

Data and Additional Definitions.—We used 2010 as the baseline year because that was the most recent period for which the US government and other independent groups had publically available reference tables when we began building the model. Before submitting this article for publication, we updated all databases, wherever possible, used as the basis for the findings reported. We have maintained the terms used in our earlier publication.[7] In particular, *FTE* is defined as the "usual number of hours a full-time pathologist normally works," which is currently a mean (SD) of 49.7 h/wk (9.7 h/wk) (median, 50 hours). *Full time* covers pathologists working from a minimum of 35 h/wk to any reported maximum.

Future Demand (Through 2030)

General Assumptions and Notes.—The framework of our demand model rests on the assumption that both the pathologist workforce (supply) and the US per capita use of pathologist services (demand) were in stable equilibrium in 2010. We evaluated several factors that might disrupt that equilibrium, such as supply exceeding demand, accountable care reducing the demand for certain high-volume pathology services, and subspecialization affecting current practices (Appendix A). In this work, and in numerous data sources, estimations are provided as high, middle, and low. The middle level, which we report, is defined as the best estimations developed as existing in the current market.

Table 2. Taxonomy and Examples of Pathologists' Services	
Service	**Description**
One patient at a time	Individual patients—each item includes all techniques for developing a diagnosis (eg, light microscopy, in vivo microscopy) and subsequent testing (eg, molecular, genetic, immunohistochemistry)
Anatomic pathology Surgical pathology	Pathology based on the organ and system, eg, breast, skin, gastrointestinal, genitourinary, and gynecologic systems, pulmonary, blood and lymph nodes, etc, and includes tumor board time as the pathologist who rendered the diagnosis; institutions variably classify molecular/genomic pathology as AP or LM
Cytopathology	Gynecologic (cervical smears), body cavity fluids, FNAs
Autopsy	General and forensic
Laboratory medicine	Microbiology, clinical chemistry, hematology, general laboratory, transfusion medicine (blood bank)
Genomic pathology	Genomic analysis of somatic (cancer) specimens, germline specimens, tissue HLA typing, and infectious disease
Real-time services	Pathologist sees patient to perform FNA, bone-marrow biopsy, in vivo microscopy apheresis
Provider consults	After rendering a diagnosis, the time a pathologist spends consulting or speaking with a clinician to discuss therapeutic implications, using electronic health records for similar purposes, or attending tumor boards as an interested expert, and acute care consultation
Population services	Services groups of patients, communities, but not the individual patient
Laboratory medical directorship	Relates to management and operation of laboratories; maintaining quality standards, policies, certifications, regulatory compliance, CAP inspections
Outcome assessment/use management	Determines whether tests performed are useful, need upgrading with new or different methodology, or should be expunged from the test menu offered; quality assurance studies; engaging other physicians to improve patient outcomes
Biorepository management	Oversees patient protection, tissue sample quality, clinical information quality, bioinformatics, and logistics
Public health	Includes POC management of chronic disease, ongoing wellness management, epidemiology
Clinical informatics	Collection, classification, manipulation, storage, retrieval, and dissemination of information to solve problems in pathology and in the care of patients
Professional responsibilities	To institutions, pathology, including the next generation of pathologists and self
Medical administration (nonoperational)	Professional activities associated with institutional committees (executive, strategic, library committee) and managerial and operational aspects of pathology laboratories on a broad level (eg, personnel, credentialing)
Teaching	Relates to residents, medical students, allied health groups, and other physician groups
Research	Generally translational research, but includes basic science
Life-long learning activities, including that used to discharge LMD activities or improve patient care activities	Maintenance of certification, compliance with federal and state regulations, journal reading
Professional societal obligation	Work in CAP committees, advocacy, participation in events, leadership
Entrepreneurship (practice management)	Running a practice, promoting a practice, including client relationship building and management; developing new models of practice, and potentially disruptive start-ups/model expansions

Abbreviations: AP, anatomic pathology; CAP, College of American Pathologists, FNA, fine-needle aspiration; HLA, human leukocyte antigen; LM, laboratory medicine; LMD, laboratory medical directorship; POC, point-of-care.

One Patient at a Time Services.—Forecasting demand requires knowledge of many factors, including the number of patients requiring services, service level, service mix (AP versus LM), US population growth and an older population requiring more services, gender mix, insurance coverage, changes in disease incidence, and the possibility of practice patterns changing as clinical guidelines, technology, and payment policies evolve (Figure 2).

Our projections used the following data (see Supplemental Table 2 for formulation of the demand equation):

Population Projections.—We obtained the US population projections by age group, gender, and insurance provider for 2010–2030E, initially using 2008 US Census data and then, the 2012 US Census data (updated in May 2013) for 2012–2060E,[14] adjusted for the middle series net of international migration.

Insurance Coverage Projections.—We used compound annual growth rates to the US Centers for Medicare and Medicaid Services (CMS) insurance coverage projections through 2019 for Medicare, Medicaid, employer-sponsored programs, and private payers to project coverage through 2030. We initially adjusted the rates according to the 2014 Patient Protection and Affordable Care Act (PPACA) to exclude and include the new Medicaid and Exchange coverage for the previously uninsured.[15–19] We obtained updated files that required some modifications, which we confirmed with CMS representatives in July 2014, from the Congressional Budget Office and CMS Web sites and used their projections of insurance coverage through 2022.

Use of Pathology Services.—No published sources stratify use of pathology services by patient profiles. Among tests available for analysis, tissue biopsy diagnoses, and complete blood cell counts (CBCs), representing use rates for AP and LM services, best approximate demand patterns for pathology services. The National Hospital Ambulatory Medical Care Survey (NHAMCS '08)[20–22] captures the rates of biopsies and CBCs ordered by age and gender across insurance categories. The National Ambulatory Medical Care Survey (NAMCS '08) and the NHAMCS '08 provide data on age and gender and includes a national sample of hospital outpatient departments to obtain data on outpatients, medication therapy, payment sources, among other categories.

We used further proxies for information on biopsy rates. For example, for the "other public insurance" category, we used a weighted mean of biopsy rates in the Medicaid and Medicare databases found in the NAMCS '09 reports.[23] We assumed the use rate for the 0 to 17 age group (a small segment of the population) to equal Medicaid use by the same cohort. We assumed that use rates

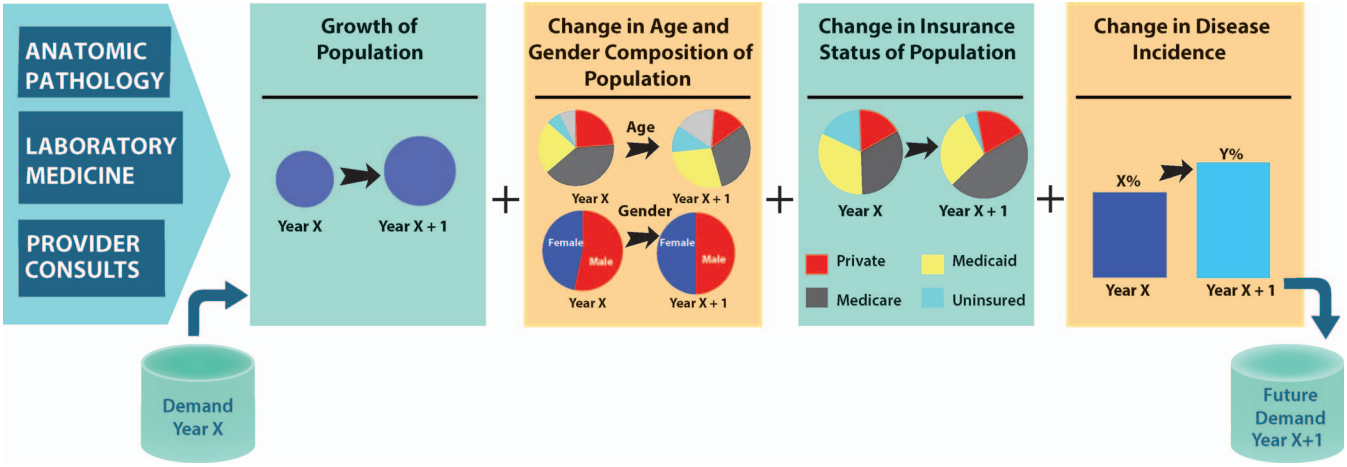


Figure 2. *Method for calculating future demands for pathologists' services.*

for insurance exchanges were similar to private insurance (employer-sponsored and other private insurance).

Population Aging and Demand for Pathology Services.—We determined AP and LM use rates for the baseline year of 2010 and assumed those rates would remain constant through 2030E. By assuming a constant-use rate, the demand rate for pathology services varied only with the changing population in each segment (see "Appendix A").

Cancer Incidence and Demand for Pathology Services.—We used the cancer incidence rates in the Surveillance, Epidemiology, and End Results (SEER 18) program for 2000–2011,[24] which provided the most recent data on cancer incidence to project future rates (report released in April 2014). For cancer-related AP and LM demand, including insurance impact, we used the same methodology as the rates of aging.

Provider Consults and Demand for Pathology Services.—When developing a primary diagnosis, pathologists often confer with clinicians, patients, or other health care team members to obtain histories or discuss therapeutic implications; consult the electronic heath record for similar purposes; and attend tumor boards as the professional who made a diagnosis or as a consultant. Pathologists may also spend time providing second opinions to pathologists outside their groups. We calculated FTE employees required from the ratio of provider consult effort to the combined AP and LM efforts for 2010. We assumed that this variable would remain constant through 2030E, but the model's flexibility permits ready testing of that assumption.

Population Services and Professional Responsibilities.—Laboratory medical directorship and medical administration focus on the management and operation of the entire pathology laboratory, not on services to an individual patient. The LMD services include maintaining and ensuring quality standards, certifications, and regulatory compliance so projections of demand must focus on services provided as part of directing the laboratory, small or large, not on population demographics. Medical administration services are the professional activities associated with institutional and nonlaboratory operations, such as executive committee participation, strategic planning, credentialing, and personnel management.

We began building LMD and medical administration services into the model by preparing a list of agencies that accredit Clinical Laboratory Improvement Amendments of 1988 (CLIA)–licensed laboratories in the United States, across all levels of complexity defined by CLIA.[25] Review of the CAP's Laboratory Accreditation and Regulatory Affairs section of the Laboratory Improvement Program indicated that the CAP and the American Osteopathic Association primarily accredit laboratories of moderate and high complexity that require quality standards and compliance norms be maintained.

We excluded data from:

- The AABB (formerly, the American Association of Blood Banks) and the American Society for Histocompatibility and Immunogenetics. Both accredit laboratories of moderate and high complexity, but almost all of those laboratories are also CAP-accredited institutions so inclusion would have duplicated efforts.
- Laboratories governed by COLA (formerly the Commission on Office Laboratory Accreditation) and principally physician-office laboratories because few pathologists direct the laboratories.

The Joint Commission serves hospitals, laboratories, and physician office laboratories. We included only the hospital-accredited laboratories. We excluded other services that pathologists seldom direct (ambulances, ambulatory surgery centers, ancillary testing sites, assisted living facilities, community clinics, end-stage renal disease dialysis facilities, federally qualified health centers, health fairs, home-health assistance providers, health maintenance organizations, hospices, independent services, industrial services, insurance services, intermediate care facilities for the mentally disabled, mobile laboratories, outpatient rehabilitation facilities, pharmacies, physician offices, practitioner services, prison services, public health laboratories, rural health clinics, school/student health services, skilled nursing facilities, and other).

We applied a similar rationale for accreditations performed under the jurisdiction of CMS by state agencies. We gathered trend-line information on the number of laboratories performing tests of moderate to high complexity, accredited from 2007 through 2014, to forecast changes through 2030E. We included a variable for changes in effort required to comply with ever-more-stringent accreditation standards.

Research and Teaching.—Demand for research services mirrors the number of pathology programs approved by the Accreditation Council for Graduate Medical Education (ACGME) for residency and fellowship training; such demand reflects the patient population only indirectly. We assumed that program leader philosophy influenced the effort devoted to research more than program participation numbers. Teaching services reflect both the work described above and medical student teaching. Using changes in the number of US pathology residency and fellowship programs, 2008–2013,[26] we projected numbers through 2030E, recognizing that those projections might be incorrect, given the changing health care environment, and the announced intentions of some smaller programs to close. In addition, changes in education delivery may influence the needed future workforce. We deter-

mined the ratio of average hours spent weekly on research and teaching (calculated by multiplying the percentage of time spent by total FTE employees in 2010) and made projections through 2030E.

Scenarios

Two C4C project teams evaluated new technologies and services in which pathologists might have leadership and/or expanded roles now or in the future. We used a gating process to score the ease or difficulty of implementing the technology or service, market demand, procedural basis, and/or utility in an accountable care organization or managed care environment. We semiquantified the anticipated or actual efforts required, both minimum and maximum, and developed algorithms for selected services, such as genomic analysis (GA), digital pathology, and in vivo microscopy—so we could include them in the model. In general, we projected their impact within a limited period (3–7 years).

We detail one scenario below (genomic medicine) and briefly summarize several others.

Genomic Pathology in Surgical Pathology (Molecular Oncology).—Genomic analysis currently has application in 4 major services: cancer specimens, germline analysis, tissue human leukocyte antigen typing, and infectious disease. This scenario focused on oncologic surgical pathology,[27,28] especially the technologies associated with gene panels, exome analyses, and genome analyses. We assessed demand with the understanding that testing emerges from the research laboratory, enters the more-regulated clinical arena, and finally merges into mainstream clinical applications.

We chose cancer as the best overall proxy for estimating the GA surgical pathology pool when calculating pathologist efforts. Of all surgical pathology cases, only a small percentage have a cancer diagnosis, but about 90% of all surgical pathology cases that undergo somatic GA are cancer cases. From the SEER 18 database (2000–2011),[24] our New Technology team determined cancer incidence rates across age groups. Of the approximately 1.9 million patients diagnosed with cancer in 2008, 1.25 million were newly diagnosed (primary tumor), and 0.65 million had recurrences (relapse tumor) (65.8% and 34.2%, respectively). We also assumed that, by 2016, about 10% of all new and recurring cancer cases would undergo GA (low and high estimates were 5% and 15%, respectively), rising exponentially from almost 0% in 2011.

Certain assumptions have been updated since 2010 (the original assumptions, if differing from those now used, are shown in parentheses): (1) essentially all cases needing GA would go to academic medical centers or reference laboratories through 2015; (2) pathologists would perform GAs once for tumor cells (and would analyze nontumor cells and possibly perform additional analyses because the tumor might harbor several distinct genomes); (3) cases with metastatic cancer, because of potential variances throughout the sites,[29] would require at least one GA and sometimes several analyses; (4) relapsed cases would require a further GA (3 additional analyses: 2 for tumors and 1 for nontumors); (5) the percentage of GAs requiring large-panel, exome, and GAs would change from 100%, 0%, and 0%, respectively, in 2011, to 90%, 5%, and 5%, respectively, in 2016; (6) several features would likely remain constant, including the percentage of relapsed-to-new cancer cases undergoing GA and the percentage of cases referred from community hospitals to academic centers and reference laboratories; and (7) the science is sufficiently mature to meet recognized criteria for insurance payments.

In 2011, large gene-panel analyses consumed 50 hours and exome analyses consumed 100 hours of a pathologist's time. Full GA was nonexistent. We projected that, by 2016, the pathologist's time required to do those same analyses would decrease to 0.5 hours for large gene-panel analyses and 2 hours for exome analyses, and GA would require 2 hours. These estimates exclude the pathologist's time spent on basic research, implementation, software development, and supervision.

GA of Germline (Inherited) Disease.—Using methodology similar to the GA of surgical specimens for cancer, this type of analysis sequences about 0.3% of specimens, half of which pathologists interpret. We assumed that academic medical centers would perform about 80% of the analyses, and reference laboratories would perform the other 20%. We expect the number of cases examined to grow exponentially (second power) after starting near 0% in 2011. We assumed 1-time testing and an equal number of exome and genome cases, with a linear shift in test distribution among large gene panel, exome, and genome analyses between 2011 and 2016. The time required for an analysis should also decrease dramatically during that period.

Digital Pathology.—We expect digital pathology to be involved in frozen section interpretations, consultation/expert second opinions, digital image analysis and multiplex high-medical-value assays (linked by the team), computer-aided diagnostics, quality assurance, and international in-sourcing. We evaluated several practice settings: academic hospital/medical centers, community/urban hospital/medical centers, and community/rural hospital/medical centers.

In Vivo Microscopy.—In vivo microscopy takes microscopic images from living tissue, without biopsy or processing. In vivo microscopy may enable making histopathologic diagnoses from tissues that are difficult or unsafe to sample, screening entire organs for microscopic disease, and understanding disease mechanisms in vivo.

New Medical Roles Pathologists May Have

The Existing and New Services Team was charged with exploring pathology services in which pathologists might have more-direct roles in patient care and add significant value.

Diminished Demand for Pathologist Services

Consolidation.—Cognizant of looming market forces that are now beginning and that may become more widespread, we examined the effects on pathology practices if those practices were to consolidate, merge, or be acquired by larger practices. Our objectives were to (1) assess the current state of the pathology market (in terms of consolidation), (2) identify major drivers for consolidation, and (3) assess the effect of consolidation on pathologists and pathology practices.

RESULTS

Current Demand for Pathologists' Services

Pathologist FTEs.—In 2010, about 17 570 FTE pathologists were in active practice in the United States (Tables 3 through 5), comprising about 2% of all US physicians (835 723).[30]

FTE Apportionment.—Most pathologist efforts (74%, 12 914 FTEs) focus on one patient at a time services, principally AP (52%, 9083 FTEs) and LM (14%, 2425 FTEs) (Table 3; Figure 3, A). Population services consume the next largest amount of effort (12%, 2196 FTEs), largely LMD (11%, 1950 FTEs), followed by professional responsibilities (14%, 2460 FTEs). Professional responsibilities include medical administration (6%, 984 FTEs) and teaching (5%, 878 FTEs). Collectively, these 5 specific efforts (AP, LM, LMD, medical administration, and teaching) account for 88% of total pathologist activities. The other major fields of endeavor (autopsies, real-time services, provider consults, biorepository management, outcome assessment, public health, practice management, research, informatics, and others) account for the remaining 12% of pathologists' work, with no single activity exceeding 3%.

Demand Across Service Areas.—*Subspecialty Effort.*—Among AP services, the gastrointestinal pathology subspecialty was the largest group (24%, 2200 FTEs); in addition,

Table 3. Baseline Workforce Forecasts (Before Health Care Reforms)

Service	Year		Forecast Year				
	2010	2012	2014E	2016E	2018E	2024E	2030E
One patient at a time							
Anatomic pathology	9083	9156	9139	9225	9356	9578	9759
Autopsy	527	527	527	527	527	527	527
Laboratory medicine (clinical pathology)	2425	2439	2441	2458	2487	2550	2603
Real-time services	281	281	281	281	281	281	281
Provider consults	316	319	318	321	325	333	340
Others	281	281	281	281	281	281	281
Population services							
Biorepository management	35	35	35	35	35	35	35
Laboratory medical direction	1950	1975	2029	2086	2114	2198	2286
Outcome assessment	176	176	176	176	176	176	176
Public health	35	35	35	35	35	35	35
Professional responsibilities							
Entrepreneurship	123	123	123	123	123	123	123
Medical administration	984	997	1024	1053	1066	1109	1153
Research	474	487	495	502	510	538	575
Teaching	878	902	917	930	945	997	1065
Total demand	17 570	17 733	17 821	18 034	18 262	18 761	19 239
Total supply (from Robboy et al[7])	17 570	17 913	17 981	17 646	17 203	15 017	14 063

Abbreviation: E, estimated.

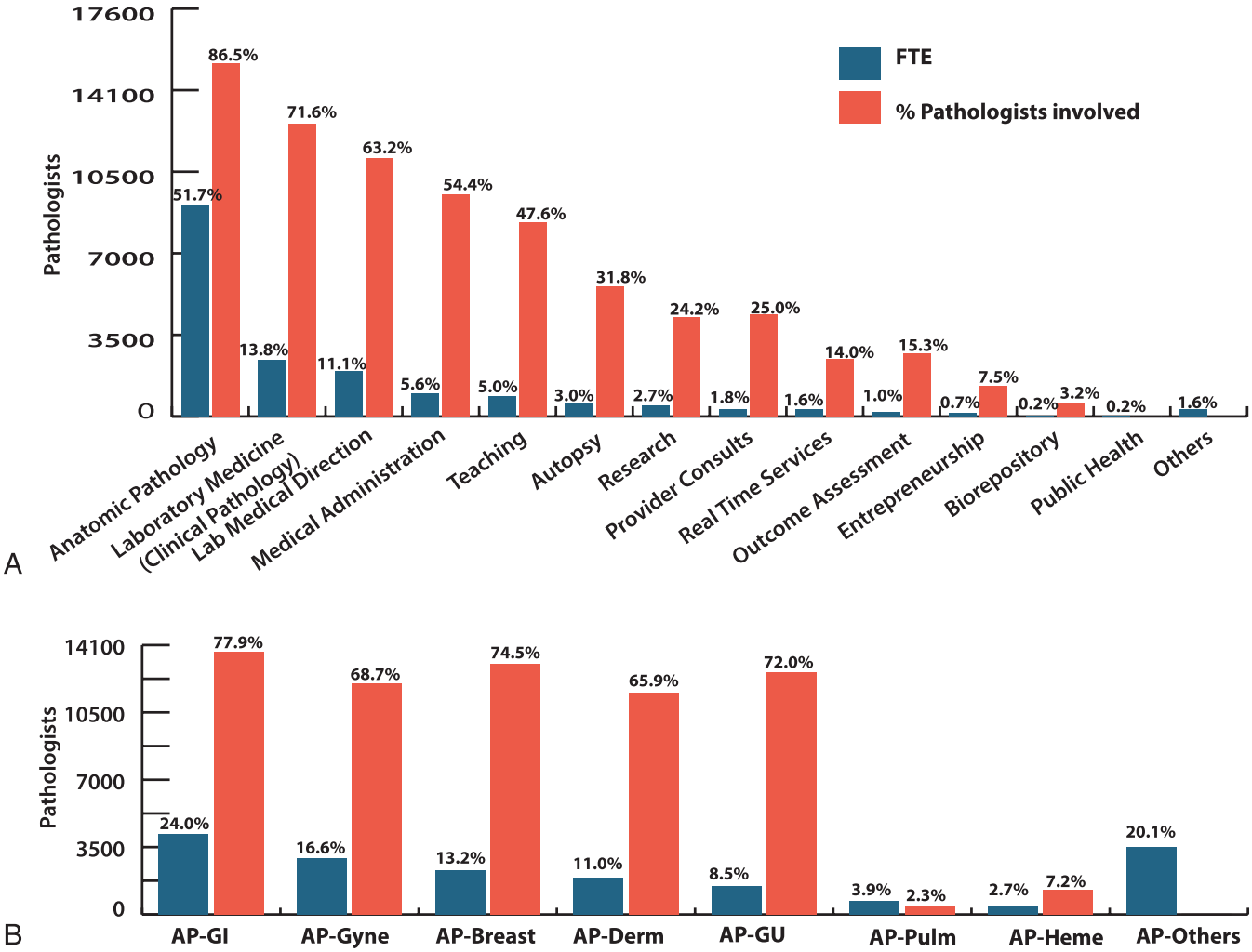


Figure 3. *Pathologists' activities in 2010 segmented across service areas. A, All areas of endeavor (corrected from PCS-11[11]). B, Surgical pathology activities (data from C4C-10[10]). Abbreviations: AP, anatomic pathology; Derm, dermatopathology; FTE, full-time equivalent; GI, gastrointestinal pathology; GU, genitourinary pathology; Gyne, gynecologic pathology; Heme, hematopathology; Lab, laboratory; Pulm, pulmonary.*

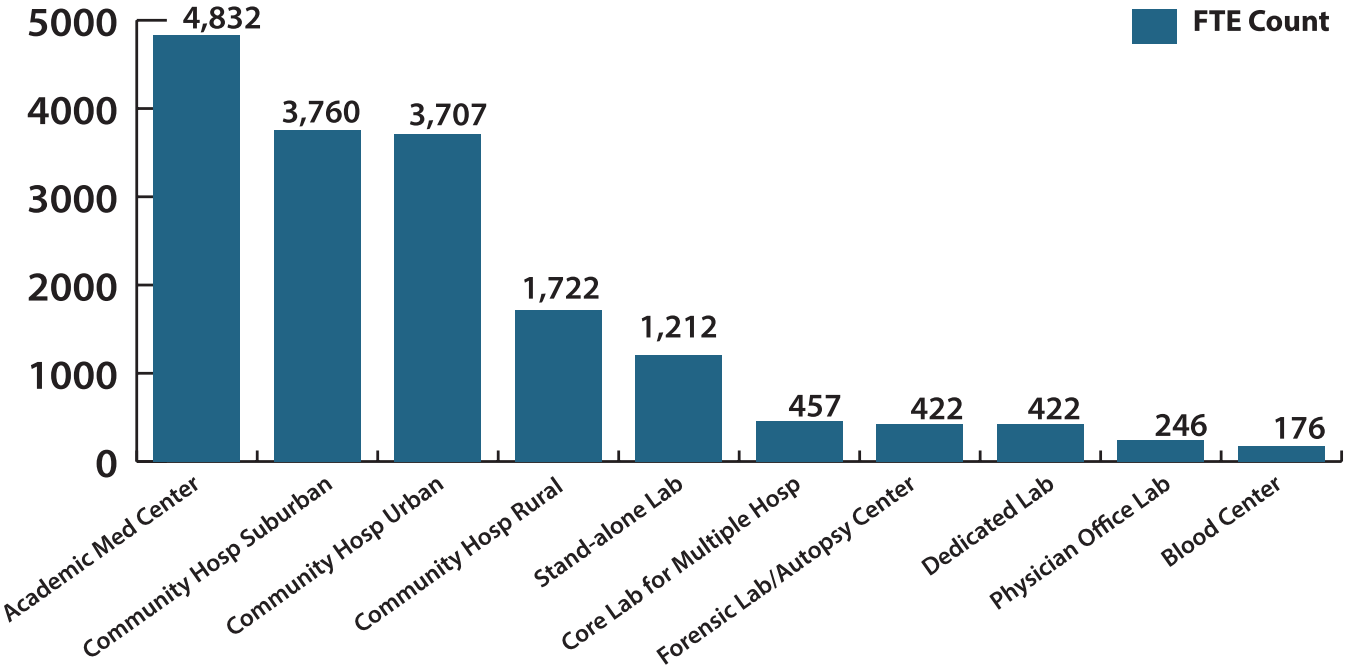


Figure 4. *Pathologist activities in 2010 segmented by base locations. Abbreviations: FTE, full-time equivalent; Hosp, hospital; Lab, laboratory; Med, medical.*

more pathologists (78%) practice in this area than any other (Figure 3, B). The next most-common areas of practice are AP-breast, AP-dermatopathology, AP-genitourinary, and AP-gynecologic pathology, with 66% to 75% of pathologists all spending some time in each of these areas. As well, 46% of pathologists work in cytopathology, primarily with gynecologic specimens. Relatively few highly trained subspecialists practice in each of the other areas (eg, hematopathology and pulmonary pathology).

Work Site.—Most pathologists (83%, 14 021 FTEs) work in clinical laboratories within hospitals or in academic medical centers (two-thirds in the former and one-third in the latter; Figure 4). Two-fifths of the community hospitals are urban, two-fifths suburban, and one-fifth rural; 17% (2759 FTEs) of pathologists work in nonhospital laboratories, almost one-half of those in standalone laboratories, with the rest divided among off-site core laboratories for multiple hospitals, forensic laboratories, physician office laboratories, and research laboratories. A few (1%, 176 FTEs) work in blood centers.

FTE Apportionment by Work Site.—Pathologists practicing in academic medical centers divide their efforts somewhat differently than pathologists in community practice do (Table 6). Academic pathologists allocate more than twice as much time to teaching, research, and hospital committees (professional responsibilities) (24% versus 11%), whereas pathologists in community hospitals focus more on AP and LM (services for individual patients). Pathologists in academic medical centers also devote slightly more effort to services for patient populations (eg, LMD and biorepository management) than pathologists in community hospitals do (18% versus 15%).

Population Factors Affecting Demand.—By 2030, the US population older than 65 years will increase nearly 80%, from about 40 million (13% of 310 million) to 71 million (19% of 374 million).

Use.—The 2009 data from physician-office practices show that use of AP services increased in women until age 64 years (213 biopsies/10 000 visits, or 14.3 times greater than the minimal-use reference point of females 0–17 years old), and then fell slightly in older age groups (Figure 5, A).[11] Compared with women, men 65 to 74 years old had more biopsies, but the findings were otherwise similar (Figure 5, B). Women older than 75 years and men 65 to 74 years old had the highest rates of CBC use (Figure 5, C and D).[23] Overall, Medicare patients averaged 7.7 biopsies per 1000 subjects in the hospital outpatient department and 303 CBCs per 1000 subjects in the emergency room.[20]

Onset of Chronic Disease.—Patient age greatly affects the incidence and prevalence of disease. In 2003, 109 million Americans had pulmonary or cardiovascular disease, mental disorders, or diabetes (162 million total diagnoses). This number will grow 42% within 2 decades.[31] Cancers are forecast to increase 62%, from 11 to 17 million, during the same period.

Insurance.—Type of insurance coverage affects the use of pathology services. Using fee for service as the index (100%), per capita usage drops to 86% in exclusive health maintenance organization (HMO) networks and to 27% for the uninsured.[32] All other managed care plans (preferred provider organizations, point-of-service plans organized as open-ended HMOs, non-HMO point-of-service plans, and other HMO/managed care plans) have usage rates approaching fee-for-service levels (98%) (Figure 6). Viewed by payor (Medicare, Medicaid, private insurance, and no insurance, respectively), the relative ratios for biopsy usage are 2.4, 2.0, 1.0, and 0.4, and for CBC usage, they are 4.1, 2.1, 1.0, and 1.4.

Future Demand for Pathologists' Services

Simple Straight-Line Projection.—If all factors stayed the same, and the current number of pathologists per 100 000 population remained stable, 10% more pathologists

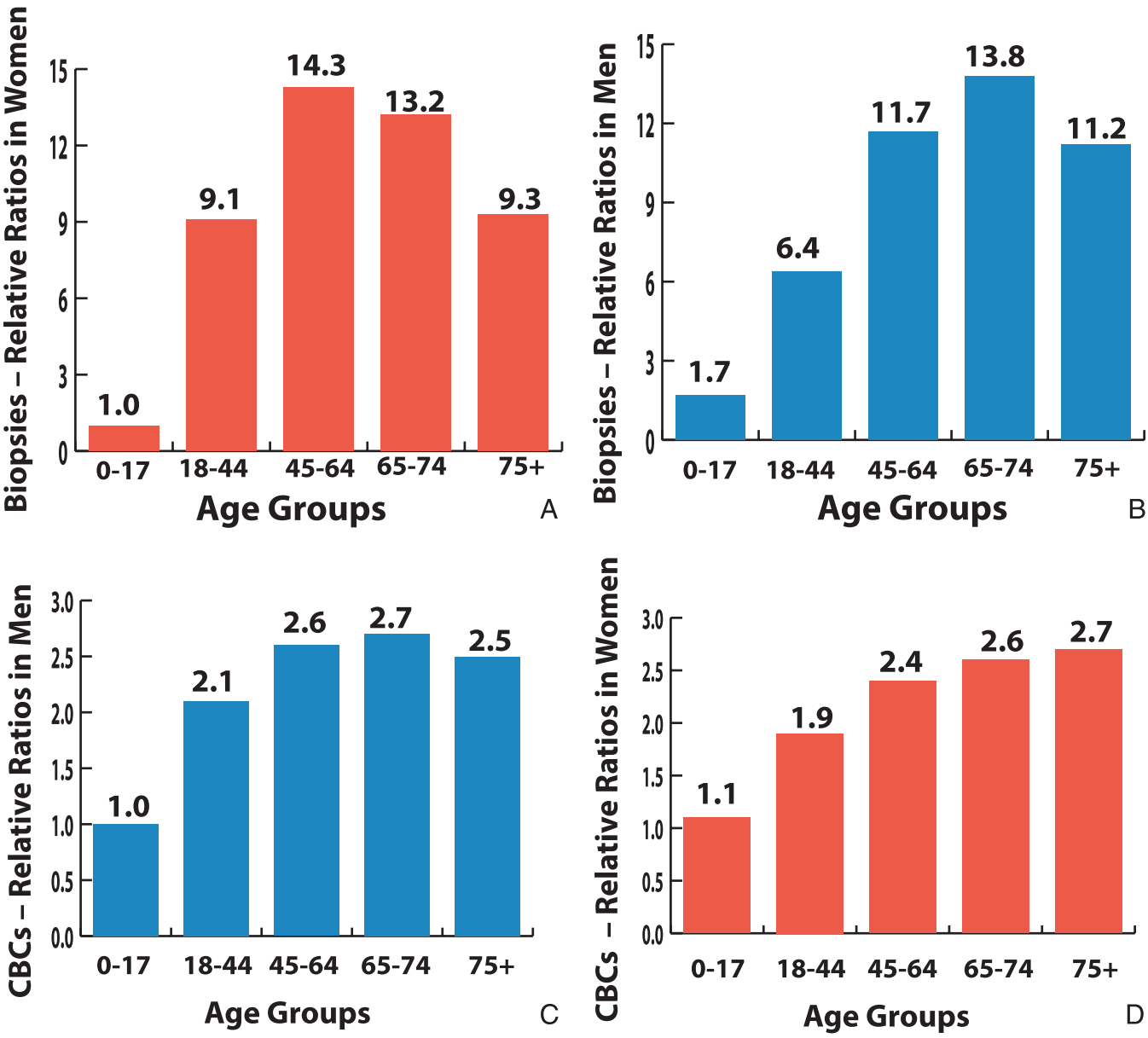


Figure 5. *Use ratios for biopsies and complete blood cell counts (CBC) by patient gender and age. A, The reference group for biopsies is women, 0 to 17 years old, where the reference point (ratio of 1) is 15 biopsies per 10 000 patient visits. B, Biopsies in men. C, The reference group for CBCs is men, 0 to 17 years old, where the reference point (ratio of 1) is 73 CBCs per 1000 patient visits. D, CBCs in women.*

to 19 239 FTE workers would be needed by 2030E (Table 3). Because of the additional support needed with an aging population, associated illnesses, and full implementation of PPACA mandates, the pathologist workforce demand forecast would rise by 16% (to 20 395 FTEs). These forecasts include all services listed in Table 4. The assumption that nothing will change (practice behavior, use, mergers, economy, etc) is highly suspect and simply a place to start applying the model (see also "Contractures" below and Appendix A).

Anatomic Pathology.—We forecast the need for anatomic pathologists to reach 9790 FTE workers by 2030E due solely to population growth and aging, or about 10 689 FTE employees with full implementation of PPACA mandates. Pathologists, both established and those new in the practice, expect major growth throughout the next decade in the

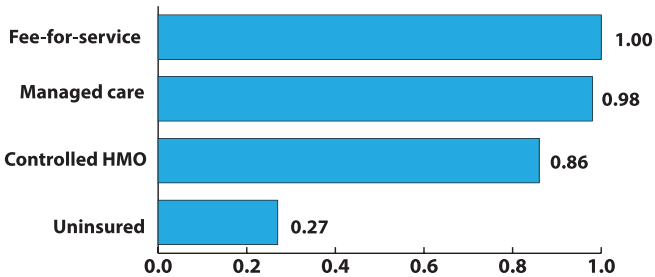


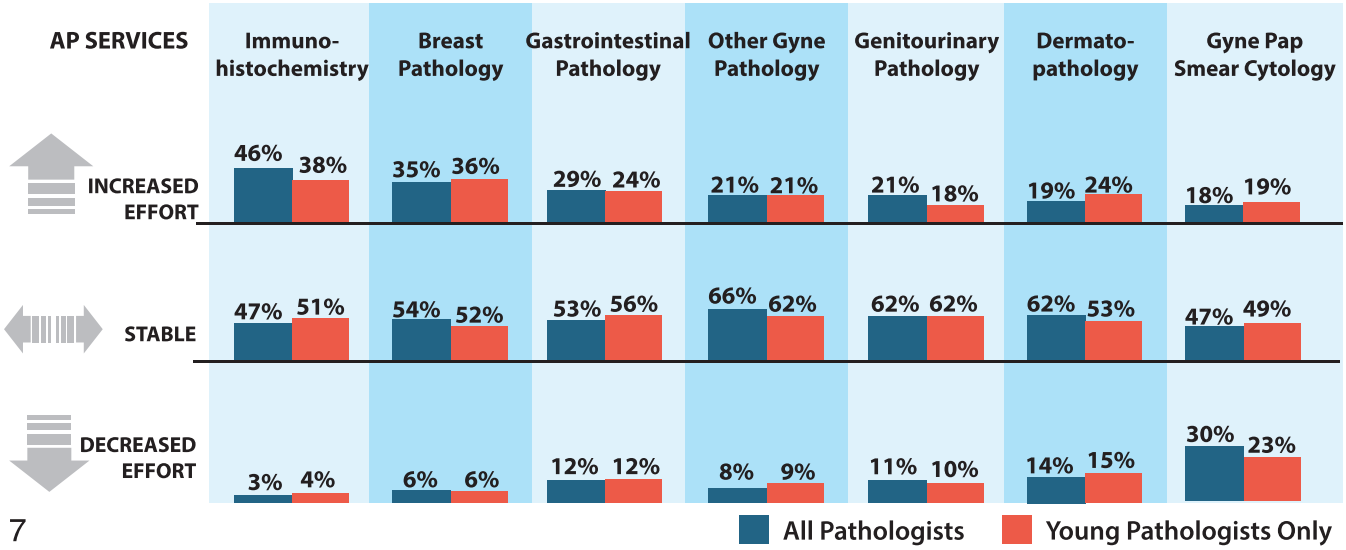
Figure 6. *Per capita index for use of pathology services (relative to fee for service) in 2000. Abbreviation: HMO, health maintenance organization.*

Table 4. Workforce Forecasts After Health Care Reforms Are Enacted[a] and Anticipated Changes							
	Year		Forecast Year				
Service	2010	2012	2014E	2016E	2018E	2024E	2030E
One patient at a time							
Anatomic pathology	9083	9199	10 124	10 628	10 707	10 680	10 689
Autopsy	527	527	527	527	527	527	527
Laboratory medicine (clinical pathology)	2425	2449	2665	2750	2756	2774	2797
Real-time services	281	281	281	281	281	281	281
Provider consults	316	320	351	368	370	370	371
Others	281	281	281	281	281	281	281
Biorepository management	35	35	35	35	35	35	35
Laboratory medical directorship[b]	1950	1975	2029	2086	2114	2198	2286
Outcome assessment	176	176	176	176	176	176	176
Public health	35	35	35	35	35	35	35
Professional responsibilities							
Entrepreneurship	123	123	123	123	123	123	123
Medical administration	984	997	1024	1053	1066	1109	1153
Research	474	487	495	502	510	538	575
Teaching	878	902	917	930	945	997	1065
Total demand	17 568	17 786	19 063	19 775	19 927	20 124	20 395
Total supply (from Robboy et al[7])	17 570	17 913	17 981	17 646	17 203	15 017	14 063

Abbreviation: E, estimated.

[a] Reflects additional pathologist full-time equivalent positions needed to provide medical services for an estimated 48 000 000 uninsured individuals as of 2012, who will become insured and receive normal care as a result of the Patient Protection and Affordable Care Act enactment.[77]

[b] See Table 5, which lists multiple scenarios for possible change in laboratory medical directorship. In this table, the need for laboratory medical directorship is calculated without health care reform envisioned.



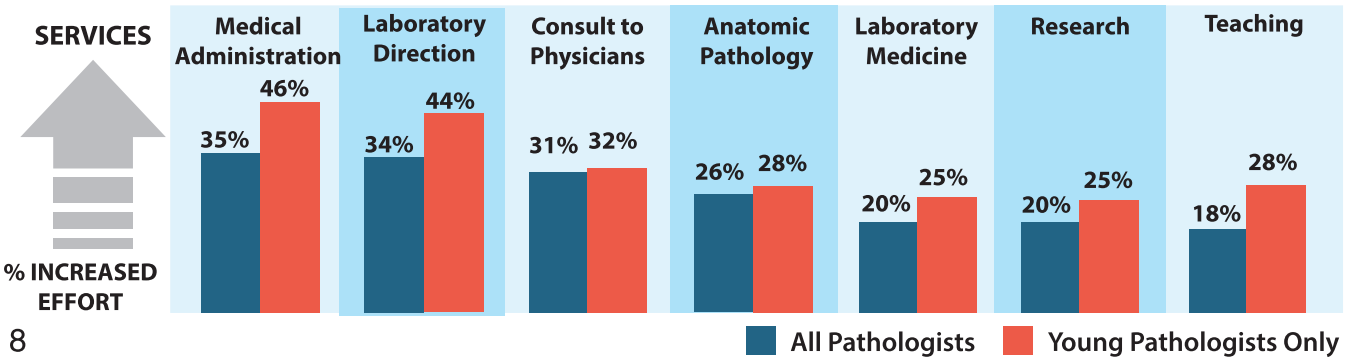


Figure 7. *Changes in effort over time that younger and all pathologists anticipate spending in differing anatomic pathology subspecialties through 2030E (N = 1052). Abbreviations: Gyne, gynecologic pathology; Pap, Papanicolaou test.*

Figure 8. *Changes in effort over time that younger and all pathologists anticipate spending across all areas of pathology through 2030E (N = 1052).*

Table 5. Scenarios for Change in Laboratory Medical Direction as Full-Time Equivalent (FTE) Positions								
Scenario	2010	2012	2014E	2016E	2018E	2024E	2030E	CAGR
Effort intensity factor remains unchanged								
FTE demand	1950	1975	2018	2041	2064	2135	2208	0.6%
Effort intensity factor increases 1% every second year								
FTE demand	1950	1995	2058	2103	2148	2289	2439	1.1%
Effort intensity factor increases 2% every second year								
FTE demand	1950	2015	2099	2166	2234	2452	2692	1.6%
1% annual laboratory consolidation starting in 2014[a] and effort intensity factor remains unchanged								
FTE demand	1950	1975	2018	1978	1938	1825	1718	−0.6%

Abbreviations: CAGR, compound annual growth rate; E, estimated.

[a] Excludes the medical administration component usually associated with laboratory medical directorship.

patient-centric services of immunohistochemistry and breast pathology (one service at a time) (46% and 35% of members, respectively) (Figure 7); 30% of members predicted that gynecologic cytology activities would decline, even before the human papillomavirus (HPV) screening won approval in April 2014 as a primary method of screening for cervical precancer.[33]

We did not model specific scenarios for how Papanicolaou test volumes might decrease precipitously because of primary HPV screening, how lower payments for multiple prostate and gastrointestinal biopsies might reduce services requested, or how vaccines being developed and deployed might reduce the number of diagnostic tests performed for precancer and cancer, including follow-up biopsies testing for recurrences. When real data become available in the future, the model will be used to refine the forecast of demand for specific services and pathologist effort.

Laboratory Medicine.—Like AP, LM is forecast to increase about 10% (to 2603 FTE) by 2030E, considering only baseline demand factors (population growth, aging, and intensity of treatment) or about 12% (to 2797 FTE) when accounting for PPACA mandates (Tables 3 and 4). No data are available to examine individual subspecialties of LM (clinical chemistry, microbiology, clinical hematology, and blood banking).

Population Services.—*Laboratory Medical Direction*.—The CLIA-approved pathology laboratories that examine specimens classified as moderate to high complexity have been growing in size and complexity. Between 2004 and 2010, the number of laboratories processing more than 500 000 samples each year increased 7.8% a year (from 125 to 182). Those processing 100 000 to 500 000 samples each year increased 5.0% a year (from 789 to 978), and those processing 10 000 to 100 000 samples each year increased 1.3% a year (from 4455 to 4692). Only small-volume laboratories (<10 000 samples each year) decreased (–0.8% a year, from 15 167 to 13 366). We assumed that every larger laboratory, but not the smallest laboratories, had one or more pathologist medical directors and multiple pathologists involved, where appropriate, in various aspects of LMD.

By our calculations, about 1950 FTE pathologists participated in LMD in 2010. If the intensity of effort remained stable, which is unlikely, we forecast 2208 FTE workers would be needed by 2030E. Knowing that the intensity of pathologist effort has increased over time, we forecast 2439 FTE employees by 2030E if the effort increased 1% during every CLIA-mandated biennial inspection cycle). The aggregate pathologist FTE workers could also drop significantly if there was substantial consolidation of laboratories, such that many were integrated into larger laboratories (Table 5; 1% annual laboratory consolidation).

Our survey data show that 44% and 32%, respectively, of pathologists younger and older than 40 expect to devote more of their time to medical direction of clinical laboratories in the immediate future (Figure 8). This reflects the broader scope of practice that pathologists will manage and the regulatory compliance required for each area (eg, population health management through point-of-care testing in the community, rather than in the hospital, and clinical informatics). In addition, as clinical laboratories handle more-diverse technologies and testing and must comply with ever-increasing regulatory requirements, pathologists will need to provide more medical direction. It may also be that some activities will be delegated to other qualified, nonpathologist staff, which we cannot measure.

If the complexity of accreditation standards were to increase and other duties involved in medical direction increased significantly (2% intensity growth factor every 2 years), we forecast the need for 2692 FTEs by 2030E to provide the required medical direction (38% increase in overall effort).

Using historic data, we assumed the number of laboratories would continue to grow. That assumption, however, might be wrong. All sectors of health care are currently experiencing philosophic and economic changes that could result in consolidation and the closing of many laboratories. If, starting in 2014, laboratories began disappearing at the rate of 1% per year because of large chains buying individual practices, outsourcing, takeovers, more waived tests, hospital closures, among other reasons, by 2030 only 8000 laboratories might remain and would require about 1718 FTE pathologists for supervision.

Biorepository Management, Outcome Assessment, and Public Health.—In 2010, these important services involved 35, 176, and 35 FTE pathologists, respectively. Biorepository management is increasingly important because policies, practic-

Table 6. Effort by Practice Setting for Pathologists Who Spend More Than 90% of Their Effort in a Single Work Location		
Service	Academic Medical Center (n = 376), (%)	Hospital (n = 559), (%)
Services for individual patients	58	74
Services for patient populations	18	15
Professional responsibilities	24	11

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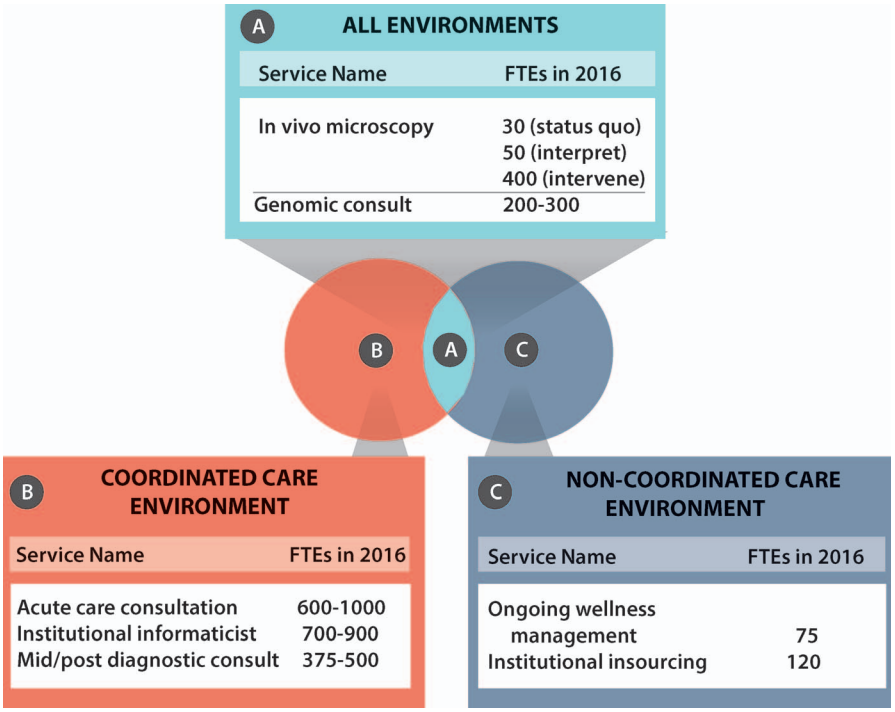

Figure 9. *New and enhanced services for pathologists with short-term potential projections. Abbreviation: FTE, full-time equivalent.*

es, and procedures continue to grow more stringent.[34–36] According to the PCS-14 survey, almost 6% of practicing pathologists say they are now involved in this area. We could not assess quantitatively how demand will develop in the future.

Pathologists are likewise getting more involved in outcome assessment and public health. Recent PCS-14 survey data show that 36% and 6% of practicing pathologists are participating in outcome assessment and public health, respectively. Again, we could not forecast demand reliably.

Professional Services.—Pathologists participate in many diverse activities considered professional services. In 2010, teaching consumed about 900 FTE employees. In academic medical centers, the teaching load outpaces all other specialties. For example, the ACGME lists 135 types of nonpathology programs. Of 66 such programs at a single university, 54 (82%) had prescribed mandatory pathology education, including teaching conferences, so the faculty devoted more than 4500 hours a year to educating nonpathology ACGME trainees.[37] No other department in the university medical center provided this level of educational support. As new medical technologies emerge, we believe pathologists will remain the link between biomedical science and the practice of medicine for many providers.

New and Enhanced Pathologist Services.—As part of the CAP transformation program, we sought to identify emerging issues and services with strong roots in new technologies in which pathologists might have important roles, and we forecasted their FTE requirements, where possible. From an initial list of 38 services, the Existing and New Services team identified 8 services in which pathologists seemed likely to succeed and for which the CAP might launch demonstration or other execution projects. (Based on our C4C learning, the CAP developed educational programs to make pathologists comfortable, if not fluent, in providing these services. For example, the CAP annual meeting included workshops on fine-needle aspiration and toxicology consultation,[38] visible roles for pathologists on tumor boards and in institutional biorepositories; and the CAP offered Web-based seminars on underused services that pathologists could provide if they mastered the skills.) The team also identified roles in which pathologists could take leadership positions in coordinated care environments. Although we did not build most of those opportunities into the model, the team calculated efforts to forecast FTE requirements (Figure 9).

Genomic Medicine.—Somatic (cancer) and inherited diseases are related areas in which small and large gene panels, exome analysis, and GA are advancing from development in the research laboratory to introduction into limited clinical arenas and soon will, most likely, be applied as mainstream clinical tools. Using 2014 estimates for 2016 and taking insurance payment policy into account, we forecasted that about 200 FTE pathologists will be needed to provide specialist services, divided as GA of cancer (about 50 FTEs) and inherited disease (about 150 FTEs). Using the more generous estimates of 2010 for 2016, we forecasted needing 225 FTE employees for somatic analysis and 150 FTE pathologists for germline analysis (375 FTEs) (Figure 10, A and B).

Digital Pathology.—We analyzed the anticipated growth in digital pathology and built algorithms into the model. Academic medical centers have been the early adopters and major users of digital pathology. We forecasted the need for about 150 users of digital pathology by the end of 2016, assuming that the US Food and Drug Administration (FDA) approves the use of this technology for primary diagnosis by then and a few users in urban and suburban hospitals after 2017.

Other Laboratory Opportunities.—Several opportunities for pathologists lie in developing new diagnostic algorithms, for example, by introducing new methods to identify organisms in the microbiology laboratory, but we could not forecast the size of those opportunities. Diagnostic algorithms rely on

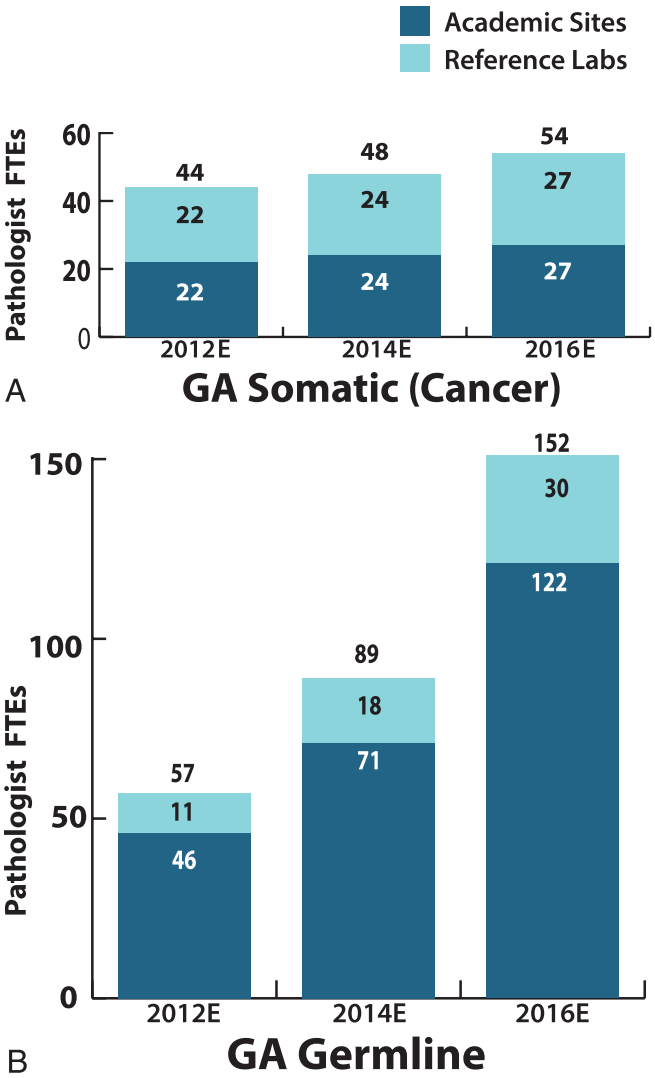

Figure 10. *Demand for pathologists' services in genomic medicine. A, Forecast in somatic (cancer) analysis. B, Forecast in germline analysis. Abbreviations: FTE, full-time equivalent; GA, genomic analysis.*

technologic advances that will enable complete analyses to be performed in dramatically less time, and they require the development of more-powerful clinical databases that expand what the pathologist clinician can do.

Reduced Demand for Pathology Services

Several current trends may reduce the number of pathologists needed in certain areas. Our model forecasted that up to about 140 FTE pathologist positions might be eliminated from the effects of laboratory mergers, by the increased prevalence of subspecialization allowing individual specialists to handle greater workloads, or from the introduction of better processes to improve efficiencies. Most consolidations would occur in suburban and urban academic hospitals (45%), but it could also happen in core laboratories serving multiple hospitals, in stand-alone laboratories, and purely academic hospitals (15%–18% each) and in rural hospitals (6%). (For results about how subspecialization can improve productivity,[39] see Appendix A, "Effects of Subspecialization").

To further explore the model's capabilities, "what if" scenarios were posed. If pathologist productivity in AP and LM (one patient at a time services category) increased by 1% annually, compounding yearly the prior years' results, 2830 fewer FTE pathologists would be needed by the year 2030E. If we also assumed that 1% of laboratories closed annually, further reducing the need for LMD (understanding that the specimens would be sent elsewhere and still need examination) and the medical administration associated with LMD, the model then forecasted the need for another 840 fewer FTE pathologists, for a total decrease of 18% (from 20 395 to 16 725 FTEs) by 2030E.

DISCUSSION

The demand for pathologist and laboratory services arises from commitment to constantly improve patient care and safety.[40] Most studies of the medical workforce, however, regardless of discipline, are supply oriented, which is relatively straightforward to measure. Supply studies ask how many practitioners are in the field, how many are leaving, how many new practitioners are in the pipeline, and whether that number is insufficient to maintain practice equilibrium, how to accelerate development, or how to find alternative practitioners.[7,9,32,41–43]

Analysis of demand is far more complex.[9,32] For pathology, a meaningful workforce assessment begins with what pathologists do today. It examines the range of services provided on a daily basis, for individual patients and the population and as professional responsibilities. The assessment also explores where pathologists conduct their activities.

Unlike most specialties, a significant portion of what pathologists do (17%) does *not* focus on a single patient (one patient at a time), but on patients collectively (population services), exemplified by the laboratory medical director role or broader medical direction, activities in which most pathologists participate to some degree. These roles involve a host of issues, from what pathologists do globally as a discipline down to minute details, such as how multiple subspecialties contribute to the effort.[44]

Demand analysis must also explore requirements for future medical care to produce optimal outcomes at lower cost.[3,45–47] Thus, we need to anticipate what advancements will improve patient care, accelerate turnaround time, provide reports that enhance the efficiency of clinical colleagues and inform patients,[48] and improve patient safety.[49] We must consider the impact of new, innovative, and even disruptive technologies,[50–53] delegation with new self-contained kits, and shifts of some current tasks to nonphysician staff who do not have or need the full set of skills that pathologists command.[54] As more medicine is practiced in the patient's home, eg, glucose monitoring, pathologists will, most likely, be increasingly responsible for ensuring the accuracy of point-of-care tests and for reporting to the health care team for possible therapeutic intervention. In the future, pathologists will have to expand their interaction with patients or treating clinicians[44,49] (including in some states by having legislative prohibitions from speaking with patients removed[55]) to better influence patient outcomes.[56] Now, and to an increasing degree in the future, pathologists' roles will expand as integral members of the multidisciplinary clinical team caring for the patient and the population of patients to achieve better outcomes and greater cost containment.

Study Strengths

We present a flexible model to test assumptions or variables to calculate supply and especially demand for pathologist services in any number of specific areas or areas later conceived. The model is flexible and allows "what if" questions to be asked.

This study developed a taxonomy of pathologists' services and service locations. In the other clinical specialties, demand depends largely on physicians examining one patient at a time. Because pathologists devote substantial effort to populations, others have had difficulty projecting demand for pathology services.[57]

Our work presents the most complete qualitative and quantitative overview to date of what pathologists do collectively as a specialty.[7,42,58–60] The work takes into account the influences of practice sites and new technologies. For example, we explored the effort required by LMD, including current effort, potential for increased effort, and potential effects of laboratory consolidation. We examined several new technologies, including the advent of genomic medicine. Our initial scenario using 2010 assumptions indicated forecasts of 375 FTE pathologists by 2016 for cancer and germline studies alone, but was tempered by 2014 assumptions to a total of 200 FTE pathologists because of third-party payment policies that sharply curtail the extent of examinations.[61] Such information will guide training programs for new pathologists, including the types of fellowships that need to expand or shrink. For example, in 2002–2003,[62] the United States had only 11 fellowship positions in molecular genetic pathology, compared with 44 in 2012–2013.[26]

Additional analyses examined new areas where pathologists could have a major effect in the next 3 to 7 years. Some of those positions fit a coordinated-care environment (acute care consultation, during or after the diagnostic consulting, optimizing laboratory use, and becoming the institutional informaticist)[63]; other roles fit a fee-for-service environment (ongoing wellness management and international in-sourcing for tissue diagnosis), and some work (in vivo microscopy and biorepository management) fits both environments.[50] Each area might employ 30 to more than 1000 pathologists.

The model enables forecasting for more or less demand based on an examination of individual factors. Other scenarios that we tested included (1) the impact on productivity of laboratory consolidation and pathologist subspecialization,[39] (2) the effects of HPV testing beginning to replace conventional cervical screening, (3) the effects of performing fewer prostate biopsies if Congress closed the in-office ancillary exceptions to the Stark Law on self-referral,[64] and (4) the effect of national legislation shifting medicolegal death investigation from coroners and lay personnel to trained forensic pathologists.

As new data become available, we will be able to apply our model to forecast more accurately the demand for pathologists' services.

Study Limitations

The limitations of our work invite further effort and improvement. The most obvious limitation lies in the truism, "prediction is difficult, especially when about the future," and the philosophic response that, over time, every job becomes archaic, so we should render our activities obsolete before someone else does. A recent, thought-provoking article entitled "In 10 years, your job probably won't exist,"[65] exhorted "almost any job that can be described as a 'process' could be done by a computer, whether that computer is housed in a robot or embedded somewhere out of sight."

Effective thinking about demand creates a climate of perpetual reinvention of jobs.[46] Like any first-generation software product, the scope of what we measured falls short of what we ultimately desire. For example, we divided AP into only the largest subspecialties, not into the ones with fewer positions, and we did not subdivide LM at all.

The most reliable public data currently comes from pathologists in group practices typical of universities or private practices, both large and small, but data to analyze efforts by service location are inadequate. We have less information about commercial laboratories and little data about pathologist activities in research organizations or the biopharmaceutical industry. For some areas, we have estimated percentages of effort that will change little in coming years, but we lack firm evidence.

With the realization of these shortcomings, our future efforts will aim to collect additional relevant data to incorporate into our model and forecasts.

The quality and age of some source data used to build the model vary. Supplemental Table 1 shows our independent grading of data availability, accuracy, and impact; not all grades are high. The model's complexity and scope and the timing of its development left many critical determinants enigmatic (ie, PPACA, as enacted, initiated varying features at differing times). We nevertheless incorporated the effects of law as proposed and enacted as a separate variable, knowing that the model's purpose was illustrative and that we can change assumptions and data at will to test "what will happen if," given a new scenario or fact.

We know that medical practice has been changing dramatically during this past decade. Between 2004 and 2011, for example, hospital admissions fell 7.8%, whereas outpatient volume rose 33.6%.[66] Although we know that pathologists' efforts in AP are generally greater for inpatient specimens than they are for most outpatient and outreach specimens,[66] we could not measure that level of granularity. Similarly, we could not measure at a granular level which types of disease cases pathologists see. For example, in Canada, the number of cancer cases per active pathologist increased 17%[67] from 1999 to 2009, but we could not analyze demand for FTE pathologists by organ system, such as the prostate as the main component of genitourinary pathology, if diagnostic workup standards are altered.

Our study also lacked a detailed database, that is, a registry housing both qualitative and quantitative data on actual tests performed for each category or disease that we could further examine by service location. Therefore, we had to use proxies, which are, at best, incomplete, for developing best practices for patient care or norms for judging outliers. More-detailed data would also enable us to examine some of the effort and expense required to comply with ever-increasing, ever more-complex regulations. There is also the concern that some variables are interrelated, and we may have overestimated or underestimated their combined effect.

All pathologists will agree that the effort spent on LMD is substantial, is often substantially undercompensated,[68] and has increased over time. The time required should be recognized by the institution and fairly compensated. The significant difference in effort required to comply with yesterday's accreditation checklists compared with today's tells the story. Calculated conservatively, the baseline model

increased the effort (intensity factor) 1% biennially. We also tested the level by increasing the effort 2% with every inspection cycle, which many consider reasonable.

The profound changes coming to health care, which are only beginning and which were not fully foreseen even several years ago, may mean that many laboratories close or combine, which would negatively affect FTE positions. We tested this possibility by asking, arbitrarily, what the effect would be if 1% of laboratories closed each year, starting in 2014. A data limitation was not knowing, for each accreditor, which of the 29 types of laboratories it accredits have pathologist or nonpathologist medical directors. Nevertheless, our model assessed the FTE effort associated with the LMD.

Although we did not set our model up to forecast the effects of state-based activities on laboratory medical director efforts, we could program the model to do so using gap analysis. For example, if the Department of Health of the State of New York enacted a proposed rule that pathologists serving as medical directors must devote at least 50% of their effort to each laboratory (so no pathologist could serve more than 2 hospitals), that would likely create an artificially severe geographic maldistribution of pathologists available to serve as medical directors.

A final limitation of the study and the model itself is our inability to integrate the roles of pathologists' assistants (PAs) and scientists with PhDs. Much PA effort substitutes for pathologist effort, but much does not. Much PA effort supplements what would largely go undone without PAs, for example, tissue preparation for biorepository use and specimen photography. We do not know how PA efforts differ in academic medical centers and community hospitals, for example, in performing gross examination of specimens for subsequent microscopic examination, which limits our understanding of the PA role needed if the anticipated shortage of pathologists materializes. Both PAs and PhDs bring distinct skills that need integration into a more holistic view of laboratory workforce demand.

Examining the Future

All informed parties acknowledge that medicine, as practiced today, could not function optimally, or even well, without pathologists. Gary Gottlieb, MD, president and CEO of Partners HealthCare (Boston, Massachusetts), reported recently on the critical role of pathology data in all health care decisions. A just-completed 5-year analysis showed that 60% of all the data points in his hospitalwide system were derived from the laboratory (500 million data points in the electronic heath record came from the laboratory versus 14 million from radiology).[69] Health care systems would disintegrate rapidly without someone to perform frozen section diagnoses during an operation, to render a diagnosis on the abnormal tissue in a biopsy or operative specimen, or to ensure the accuracy of laboratory values (identical results whether a sample is evaluated in Seattle, Miami, New Delhi, or Beijing).

Although concern in the United States about the adequacy of physician coverage is great, almost all workforce commentaries focus on primary care physicians, as reflected in a recent issue of *Health Affairs* devoted to redesigning the health care workforce.[70] Only one article, to our knowledge, even mentions pathology[58] and then does so generically in a single sentence acknowledging that the specialty may face a shortage of practitioners in the future. Of interest, a recent Association of American Medical Colleges publication[71] states that, between 2000 and 2010, the total number of pathologists in active practice declined by 7.4%, in contrast to our studies indicating that the retirement cliff leading to a net decrease in pathologists is only now beginning in the United States.[7] Also, the US Health Resources and Services Administration[72] forecasted that the supply of pathologists would increase 11% by 2025 to 19 700 FTE positions, and another modeling system[57] suggested an increase of 1%, contrary to our analysis. If our variables remained stable, our model forecasted that, by 2030, the United States would need a net 1700 more FTE pathologists, rather than the anticipated drop of 3500 FTE positions (to 14 000 FTEs), due primarily to retirements.

In an excellent forward-looking review entitled "Quality of pathology services: new strategic directions required," Godfrey Isouard[3] outlined critical planning issues. Models like ours can provide data but they are not substitutes for cogent leadership, strategic thinking, and the application of concepts such as adding value, reducing waste, and abandoning less-effective methodologies.

Clearly, as various observers have noted, the laboratory, including the role of pathologists within it, is changing rapidly.[13,46,48] Effective thinking about demand can create a climate where roles are reinvented and new services and programs are introduced, as in the CAP's recent *Promising Practice Pathways*.[73] Although pathologists understand the critical role they have in a well-functioning health care system, we must find ways to add more clinical value outside the laboratory, improve downstream clinical quality and outcomes, and generate downstream clinical cost savings. Further improvements to monitor and ensure patient safety will be important so that results posted in electronic health records or transmitted through smart phones, tablets, and other new communication methods, such as patient portals, are conveyed in appropriate context and form and without error.[10,73–76] We need to master the emerging media, learning to create and better communicate.[65] We need to become comfortable with large data sets and to develop methods to make sense of the data, to find clues and trends that can be acted on. We need to improve the management of cognitive loads and to develop better thinking skills so we can sieve what is useful and work better in teams.

In summary, we have developed a dynamic, interactive software tool for modeling pathologists' activities and performing qualitative and quantitative forecasting for both current and new areas of effort. With this model, we can test and modify hypotheses and examine implications for pathologist workforce requirements, including financial consequences. In developing the model, we also developed a new taxonomy for the practice of pathology, which includes work done for populations as well as individual patients one at a time, which thus differs from the taxonomies of all other clinical specialties.

Medicine in general, not only pathology, is experiencing unprecedented change. We foresee emerging technologies that will drastically alter the laboratory (eg, nanotechnology, in vivo single-cell diagnostic analysis and therapy, and real-time capture of patient data, in sickness or health, regardless of location). The new technologies employed today, such as genomic medicine and informatics, represent a significant opportunity for pathologists. We foresee that the ever-changing delivery of health care will foster pathologists to provide and ensure the highest-quality of diagnostic testing and accurate reporting of clinical information to improve outcomes and maximize patient safety. The challenge we

foresee will be to apply our model to evaluate demand more accurately so it can better determine the number of pathologists needed to efficiently and effectively care for patients and populations of patients by providing correct diagnoses, chronic disease management, and optimizing treatment decisions.

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APPENDIX A
Assumptions Made in Building Demand Model

Potentially Disequilibrating Factors.—*Pathologist Supply.*—Although our model assumes that, in 2010, the supply of pathologists equals the demand, that may not represent an optimal equilibrium. Because the American Board of Pathology dropped its requirement of a "credentialing" year after residency training, the percentage of pathology residents taking fellowship training increased to 96% in 2013, with 38% taking 2 or more fellowships; 27% report taking fellowship training to achieve or enhance employability or to cope with the lack of alternative employment. This amounts to a yearly "reserve" pool of pathology fellows representing 1.32 graduating residency classes, with 0.96 pursuing fellowship training to fulfill their career goals and the remaining 0.36 (approximately 220 pathologists), which constitutes an incremental pool of fellows, available for employment.[78]

Present Per Capita Demand for Anatomic Pathology Services.—A recent US Government Accountability Office (GAO) report[64] concluded that a clinician ownership interest in a laboratory providing anatomic pathology (AP) services creates an economic incentive to obtain excessive numbers of biopsies (self-referral). That study was designed conservatively to address only self-referral involving the technical component of services for Medicare patients and considered only biopsy specimens for selected common indications from urologists, gastroenterologists, and dermatologists. On that basis, the "GAO estimates that in 2010, self-referring providers likely referred over 918 000 more anatomic pathology services than if they had performed biopsy procedures at the same rate as and referred the same number of services per biopsy procedure as non-self-referring providers."(p1)

The GAO's conservative finding of a 39% to 47% increase in AP services by self-referring urologists parallels an earlier study that used more-comprehensive criteria for self-referral and found a 72% increase in prostate biopsies.[79] Regulations to end self-referral of AP services, as well as the current trend toward transition to accountability for care, may curtail this practice, but with consequences for pathologists. Although no single measure of specimen numbers that a full-time pathologist can comfortably evaluate exists, an international study comparing the various proposed AP workload measures concluded that approximately 3500 general diagnostic biopsy specimens make a fair approximation of one FTE pathologist.[21,80] At that level, economically driven, excess AP services identified by the GAO study would correspond to approximately 266 FTE positions.

Effects of Subspecialization.—AP productivity analysis reflects the aggregate of all pathology practices for all CAP members. Although institutions with sufficient volume and need for considerable diagnostic agility have long recognized the AP efficiency benefit of subspecialization, this has not been practical in small practices. In one large system, consolidation of several medium-sized practices without subspecialization into a single larger group practice where all members subspecialized, increased productivity 66%, measured by relative value units (RVUs)/FTE.[21,39]

Other limiting factors to consider are the additional years of training required and the need to maintain certain levels of general skills (because most subspecialized pathologists still participate in general operating room consultations). Although not expected until 2017, the US Food and Drug Administration (FDA) approval of whole slide imaging for primary diagnosis could lower that operational threshold so that, by collaborating or contracting, AP practices would benefit from subspecialty increases in efficiency. The extent and timing of any efficiency offsets on pathologist workforce demand are speculative, but the potential magnitude means that this possibility warrants exploration.

Segmentation of Demand Across Service Factors and Locations.—To build the baseline demand scenario, we projected FTE positions for individual services through 2030. For the base year 2010, demand was the sum of segmented demand across service factors. Because we did not forecast demand within AP subspecialties, we used the percentage split derived from C4C'10 to distribute projected demand in AP across its subspecialties. To segment FTE position demand across base locations, we used data from PCS'11 (as a percentage of total time). We assumed early in the project that the percentage distribution of time across service factors and base locations would remain constant through 2030, but accountable care economics might disproportionately affect several specific subspecialties.

Changes Affecting Demand

The baseline demand was predicated on secondary research and input from panel members. We assumed the status quo would prevail through the projected period. The baseline estimates added demand within individual service factors for a particular year based on assumptions through 2030E: (1) relative use rates across age groups and insurance categories remain constant, (2) disease incidence rates follow the trend measured during the past 5 years, (3) the ratio of FTE positions in provider consults (AP:CP) remains constant through 2030E, (4) the growth rate of pathology training programs (residency and fellowships) remains constant, and (5) the growth rate of nonwaived and complex testing remains constant.

The model included 3 built-in scenarios (high/baseline/low) and has the functionality to add many user-defined scenarios. The scenario functionality lets a user change the values of scenario variables throughout the projection period and to save the new demand for comparison with other scenarios (built-in and user defined). The model has 4 demand scenario variables: change in insurance status, change in disease incidence, change in pathology programs, and change in count of accredited and nonwaived laboratories.

In creating scenario functionality for the built-in scenarios, we defined variable maxima and minima to guide users when creating their own scenarios. The final values rested on the following assumptions.

Change in Insurance Status.—Health reform has begun in the United States. The percentage of uninsured, per the Patient Protection and Accountability Act (PPACA), provides a proxy for modeling the high scenario. We had anticipated that a low scenario might not apply to this variable, but the number of self-insured who may lose their coverage as an unintended consequence of the PPACA rollout remains uncertain. We can add scenarios based on other forces that become relevant in the next few years, for example, younger people who choose to pay a fine rather than obtain coverage under a law requiring insurance.

Change in Disease Incidence.—Disease incidence is a broad topic, and building it as a scenario may not affect demand. We believed that various factors are likely to affect disease incidence and selected the high-impact factors for the scenarios. We believed that the following factors will affect disease incidence:

1. *Human papillomavirus (HPV) screening/vaccination*.—Pathologists spend considerable time on gynecologic cytopathology, but guidelines on HPV screening might change, reducing time spent on gynecologic cytopathology. This looks especially likely because, in April 2014, the FDA approved a specific DNA-based HPV test for primary screening.[33]
2. *Behavioral changes*.—For example, quitting smoking, using sunscreen, following nutritional programs that list calories on menus, avoiding higher insurance premiums for obesity, among others.
3. *Advanced disease screening*.—We expect such screening, especially genomic testing[81] and pharmacogenomics for evaluation of drug therapy, to increase demand for pathology services. This highlights that the pathologist's role in screening may change, as exemplified in the "In Vivo Microscopy" section.
4. *Technology breakthroughs*.—We foresee emerging technologies that will alter the laboratory (eg, nanotechnology, in vivo single-cell diagnostic analysis and therapy, and real-time capture of patient data). The new technologies employed today, such as genomic medicine and informatics, represent a significant opportunity for pathologists.

Changes in Pathology Programs and the Count of Accredited and Nonwaived Laboratories.—We used the historic growth rates in residency programs as a baseline scenario for the change in demand for research and teaching services. We also used the historic growth rate of nonwaived and complex testing laboratories as a baseline scenario for the change in demand for research and teaching services.