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REVIEW

What Is the Optimal Primary Care Panel Size?

A Systematic Review

Neil M. Paige, MD, MSHS*; Eric A. Apaydin, PhD, MPP, MS*; Jeremy D. Goldhaber-Fiebert, PhD; Selene Mak, PhD, MPH; Isomi M. Miake-Lye, PhD; Meron M. Begashaw, MPH; Jessica M. Severin, BS; and Paul G. Shekelle, MD, PhD

Background: Primary care for a panel of patients is a central component of population health, but the optimal panel size is unclear.

Purpose: To review evidence about the association of primary care panel size with health care outcomes and provider burnout.

Data Sources: English-language searches of multiple databases from inception to October 2019 and Google searches performed in September 2019.

Study Selection: English-language studies of any design, including simulation models, that assessed the association between primary care panel size and safety, efficacy, patient-centeredness, timeliness, efficiency, equity, or provider burnout.

Data Extraction: Independent, dual-reviewer extraction; group consensus rating of certainty of evidence.

Data Synthesis: Sixteen hypothesis-testing studies and 12 simulation modeling studies met inclusion criteria. All but 1 hypothesis-testing study were cross-sectional assessments of association. Three studies each provided low-certainty evidence that increasing panel size was associated with no or modestly adverse effects on patient-centered and effective care. Eight studies provided low-certainty evidence that increasing panel size was associated with variable effects on timely care. No studies assessed the effect of panel size on safety, efficiency, or equity. One study provided very-low-certainty evidence of an association between increased panel size and provider burnout. The 12 simulation studies evaluated 5 models; all used access as the only outcome of care. Five and 2 studies, respectively, provided moderate-certainty evidence that adjusting panel size for case mix and adding clinical conditions to the case mix resulted in better access.

Limitation: No studies had concurrent comparison groups, and published and unpublished studies may have been missed.

Conclusion: Evidence is insufficient to make evidence-based recommendations about the optimal primary care panel size for achieving beneficial health outcomes.

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For author affiliations, see end of text.

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* Drs. Paige and Apaydin contributed equally to this work.

A key component of population health is the primary care physician, who is responsible for the care of a defined number of patients. Determining the optimal panel size for a full-time primary care physician is a complex undertaking that requires balancing the demands of the system (patient access to care, clinical effectiveness or quality, patient experience, and cost) with the needs of the provider team (physician and team satisfaction, adequate time for care, and avoidance of physician and team burnout). Primary care panel size varies considerably in the literature (from <1000 to >4000 patients per full-time physician), and whether this level of variability is justifiable is unclear.

A common method for calculating a provider's panel size has been to multiply the number of available slots each day by the number of days the provider works in the clinic and then divide the product by the average number of visits each patient will make each year (usually the actual number of visits in the previous year). This method does not account for many tasks that occur outside traditional face-to-face clinical visits, including patient communication (letter writing, telephone calls, e-mails, and form completion), test follow-up, panel management activities, and care coordination. It also ignores the division of work among primary care teams and the effects of different panel sizes on clinical quality. For example, studies have estimated that it would take 7.4 and 10.6 hours per day, respectively, to deliver guideline-recommended care for prevention and treatment of 10 chronic illnesses in a panel of 2500 patients (1, 2), implying that a smaller panel than this was necessary for high-quality care to be delivered. To help providers and policymakers make data-based decisions about panel size, we conducted a systematic review on the association of panel size with 6 major aims of quality health care and provider burnout.

METHODS

This review is part of a larger review commissioned by the Department of Veterans Affairs (VA) (3). The protocol for it was developed and submitted to the VA Evidence Synthesis Program Coordinating Center.

Data Sources and Searches

We searched PubMed, Scopus, EMBASE, and Web of Science from inception to 3 October 2019 using the terms *panel size*, *primary health care*, *patient concentration*, *panel design*, *patient panel*, *patient sample*, *physician panel*, *physician workload*, and *practice list size* (**Appendix Table 1**, available at Annals.org). We also searched Google on 30 September 2019, starting with the term *primary care practice size* and then using the Google-generated terms *Medical Group Manage-*

See also:

Editorial comment

ment Association (MGMA) panel size, *primary care panel size benchmark*, *patient panel size worksheet*, *Kaiser Permanente primary care panel size*, and *risk adjusted panel size*. We looked at the first 50 results for each Google search. We also reviewed references of relevant articles. Because our focus was U.S. or similar health care systems, we restricted the searches to English-language articles.

Study Selection

Three authors (N.M.P., E.A.A., and P.G.S.) independently screened titles and abstracts in triplicate. Disagreements were reconciled through group discussion. Full-text review was conducted in duplicate by 2 independent team members, with disagreements resolved through discussion. We selected research (regardless of study design) with original data that examined the association between panel size and an outcome of interest or that presented a model that related panel size to a health care outcome. The patient population could include adults, children, or both. Outcomes had to include provider burnout or 1 of the 6 aims of quality health care proposed by the National Academy of Medicine (formerly the Institute of Medicine) (4): safety, efficacy, patient-centeredness, timeliness, efficiency, and equity. We considered clinical quality, access, and costs as measuring aspects of efficacy, timeliness, and efficiency, respectively.

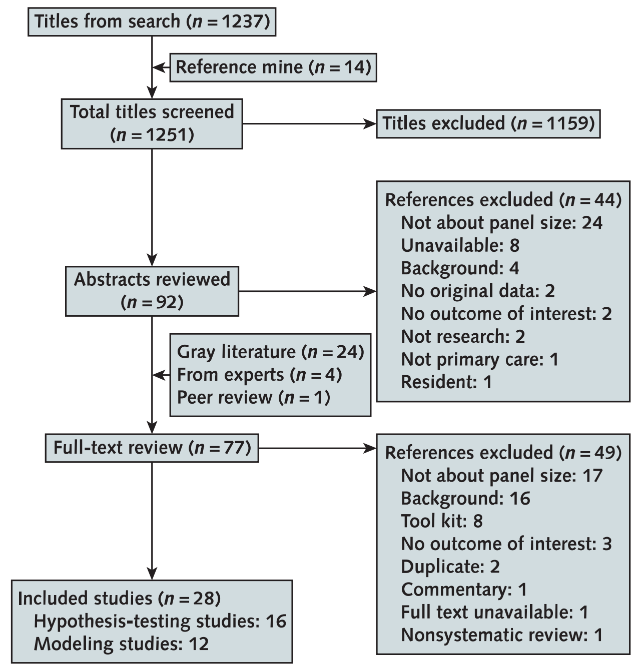
Data Extraction and Quality Assessment

Data extraction was done in duplicate. All discrepancies were resolved via full group discussion. We abstracted data on practitioner type, study design, sample size (number of practices), panel size range, other factors used as control variables, and the aims of health care plus provider burnout. The one interventional study we identified was assessed for quality using the National Institutes of Health's Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group (5).

Data Synthesis and Grading

Our synthesis is narrative and considers studies in 3 groups. The first group included hypothesis-testing studies for which the primary explanatory variable was panel size and the dependent variable was 1 or more of our outcomes of interest. The second group included hypothesis-testing studies of some other explanatory variable on outcomes of interest, for which the investigators also reported panel size as a covariate. We distinguished these groups by whether "panel size" (or another term that the authors then defined as panel size, such as "provider workload") appeared in the title of the article. If it did, we considered the study to be in the first group; if not, we classified it in the second group. The third group included studies that built simulation models to determine panel size and reported an outcome of interest. These studies were assessed by a modeling expert (J.D.G.). This involved evaluating the degree to which the studies addressed aspects of a logic model that underlies the motivation for optimizing panel size, including patient demand for primary

Figure. Evidence search and selection.



care provider visits and other non–face-to-face primary care provider services and effort; supply of available primary care provider appointments and time for other non–face-to-face primary care provider services and effort; outcomes; and value, meaning a combination of the range of benefits and costs to determine whether a certain panel size is ultimately worth the costs.

Evidence certainty, preliminarily assessed by 1 author (P.G.S.) and confirmed by consensus discussion, was assessed using criteria adapted from the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach (6).

Role of the Funding Source

Funding was provided by the VA Quality Enhancement Research Initiative, which had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication.

Results

Of 1251 screened titles, 77 publications underwent full-text review. Forty-nine of these were excluded (Appendix Table 2, available at Annals.org), leaving 28 publications that met the inclusion criteria (Figure). Details of the included studies are presented in Appendix Tables 3 and 4 (available at Annals.org) and in the full evidence report (3).

Hypothesis-Testing Studies of Panel Size

Ten studies (7–16) had a stated primary purpose of evaluating the association between panel size and an outcome of interest; 9 of these were cross-sectional. The remaining study was a pre–post study of a new method of constructing panel sizes based on patient characteristics (10). Settings included the VA (13–16); U.S. academic health centers (7, 9–12); and Ottawa, Canada (8). The mean or median panel size was about 1200 patients in 4 studies (11, 13, 14, 16), was less than 600 patients in 2 studies (9, 12), was much greater than 1200 patients in 3 studies (with upper limits 2 to 4 times that) (7, 8, 10), and was reported as being above or below the "optimal" panel size in 1 study (15).

Safety and Efficacy (Clinical Quality)

No study assessed the relationship between panel size and measures of patient safety. Three studies assessed the association between panel size and measures of clinical quality (7, 8, 13). In a VA study based on data from 2004, Stefos and colleagues (13) used multivariable logistic regression to assess the association of panel size (mean, 1206 patients) with 8 measures of clinical quality in 1 fiscal year, mainly via chart review. Additional variables were included in the model, such as number of examination rooms, staff full-time equivalent, patient age greater than 65 years, sex, distance between the patient and the treating facility, and a measure of patient risk. Multivariable analysis showed that increasing panel size was associated with lower standardized odds of a patient receiving appropriate pneumococcal vaccination and being screened for alcohol misuse (adjusted odds ratios [AORs], 0.95 [95% CI, 0.91 to 0.99] and 0.94 [CI, 0.89 to 0.99], respectively). This translates to an estimated 5% decrease in vaccination and a 4% decrease in alcohol screening with a 1-SD increase in mean panel size from 1206 to 1566 patients. Of the other 6 clinical quality measures, 4 had ORs of worse care that were not statistically significant (hemoglobin A_{1c} target of <9% for patients with diabetes, hyperlipidemia screening, full lipid profile among patients with ischemic heart disease, and diabetic retinal examination), 2 had an OR of 1.0 (colorectal cancer screening and blood pressure target of <140/90 mm Hg for patients with hypertension), and none had an OR of better quality with increasing panel size.

In a study of 36 clinicians in the Family Medicine Department of the Mayo Clinic, Angstman and colleagues (7) assessed the relationship of panel size with a composite measure of clinical quality for patients with diabetes over monthly or quarterly periods. The adjusted panel size ranged from 1876 to 4828 patients. The multivariable analysis was adjusted for patient differences using the Hierarchical Condition Categories. Increasing panel size was negatively associated with clinical quality of diabetes care (P = 0.03).

The third study (8), from Ottawa, Canada, assessed the relationship between panel size for 4195 physicians and measures of cancer screening, chronic disease management, admissions for ambulatory care–sensitive conditions, and emergency department visits over 2 years. Panel sizes ranged from 1200 to more than 3600 patients (clinicians with panels of <1200 patients were excluded from the analysis). Analyses adjusted for patient complexity found that the likelihoods of being up-to-date on screening for cervical, breast, or colorectal cancer decreased slightly as panel size increased. For example, colorectal cancer screening ranged from 45.6% in practices with the smallest panels to 44.4% in those with the largest panels. Six performance measures for patients with diabetes showed no statistically significant differences across panel sizes. The likelihood of a patient with heart failure getting an echocardiogram increased with increasing panel size (from 69.4% [CI, 67.3% to 71.3%] to 75.5% [CI, 72.9% to 77.8%]). Admissions for ambulatory care–sensitive conditions increased with increasing panel sizes (by 1.25 admissions per 10 000 patients), whereas emergency department visits decreased (from 19.5 to 17.4 per 100 patients per 2 years).

Patient-Centeredness

Three studies assessed the association between panel size and patient-centered care, generally measured as patient experience or satisfaction (7, 13, 15). Two of these were described in the previous section (7, 13); both reported no statistically significant association between panel size and patient satisfaction. In the third study, Mohr and colleagues assessed the association of workload (defined as panel size) with 3 measures of patient experience taken from the VA Survey of Healthcare Experiences of Patients (15). In their multivariable analysis that controlled for patient and organizational characteristics, workload (panel size) was associated with more patient complaints (AOR, 1.71 [CI, 1.19 to 2.47]), worse provider time availability (AOR, 0.61 [CI, 0.44 to 0.86]), and fewer positive ratings of overall visit quality (linear regression estimate [± SE], −0.20 ± 0.08).

Timeliness (Including Access)

Eight of 9 studies assessed timeliness of care, measured as either access or continuity. Three of these studies have been previously described. In the study by Stefos and colleagues using VA data, a 1-SD increase in panel size was associated with a 2.04-day increase (SD, 0.278 day) in waiting time (difference between the date scheduled for a primary care appointment and the actual date seen in the clinic), but this was not statistically significant (13). The study by Angstman and colleagues from the Mayo Clinic found that increasing panel size was associated with longer times to the third next available appointment (P < 0.01) (7). The study from Ottawa found a shallow, U-shaped curvilinear relationship between deciles of panel size and continuity, with a difference between the highest (panel size of 2400 or 2100 patients) and lowest (panel size of 1200 patients) continuity scores of about 3% (8).

Two studies, 1 from the VA (mean panel size, 1178 patients) and 1 from Oregon Health & Science University (mean panel size, 577 patients), used multivariable models and found no statistically significant association between panel size and the Usual Provider Continuity

Index (12, 14). However, a study of 114 primary care physicians in the Ohio MetroHealth system (mean panel size, 1146 patients) found that the time to the third next available appointment was positively related to panel size (r = 0.22; P = 0.032) (11). A multivariable analysis in a study of medical resident clinics during a 9-week period, with a mean panel size of 55 patients, found that patient continuity decreased by 1.4% (SE, 0.3%) for every 10 additional patients in the resident's panel (9).

In the only longitudinal, interventional study we found, Kamnetz and colleagues evaluated the effect of panel weighting during a 4-month period (panel size range, 1244 to 2315 patients before weighting and 949 to 2705 patients after weighting) on access among 112 primary care providers in the University of Wisconsin system (10). After weighting panels by patient age, sex, and insurance type (Medicare, Medicaid, or other), the total number of active patients increased by 2%, but the number who strongly agreed that an appointment in general internal or family medicine was available when needed also increased (from 70% to 75% [depending on the clinic] to 75% to 80%; P < 0.05). This study was judged as fair-quality due to its retrospective design, with only a single time point before and after the intervention.

Efficiency (Including Cost) and Equity

No study assessed the relationship between panel size and efficiency or cost. One study assessed the association between charges and panel size (7), but charges are not a good measure of cost. No study assessed the relationship between panel size and measures of equitable care.

Provider Burnout

One cross-sectional study assessed panel size as a primary explanatory variable for physician burnout (16). This study assessed 1517 VA primary care physicians (response rate, 32.9%) who responded to an online survey during 2 months in 2014 about their work experience, then linked the responses to VA data on primary care workload. Panel overcapacity was defined as a panel size greater than 1200 patients for a full-time clinician. Physician burnout was measured using a single item from the Physician Worklife Study (17) on self-reported level of burnout using a 5-point scale. In univariate analyses, burnout was higher in respondents who had overcapacity than in those at or under capacity (53.3% vs. 48.0%). In a multivariable analysis that controlled for other aspects of practice, such as whether the primary care team was fully staffed or working extended hours, the degree of clinic staff turnover, and average patient comorbidity, panel overcapacity had an increased AOR of burnout (1.19 [CI, 1.01 to 1.40]).

Hypothesis-Testing Studies of Other Questions That Included Panel Size as an Explanatory Variable

Six studies reported results of tests of the association between panel size and an outcome of interest (18–23). These studies had mixed results, and were reported in insufficient detail to judge the findings, involved health care systems or countries with panel sizes that would be extraordinary by U.S. standards, or were judged to be at high risk of publication bias.

Modeling Studies to Determine Panel Size

Twelve studies created and evaluated models to determine how to optimize panel size in primary care (24–35). These involved 5 distinct models in 2 studies by investigators at the University of California, San Francisco (24, 28); 6 studies by Balasubramanian and colleagues (25, 27, 29, 31, 33, 34); and 1 study each from Columbia University (26), Miami, Florida (30), and Tampa, Florida (35). Details of included studies and how they were evaluated are presented in the Appendix (available at Annals.org) and **Appendix Table 4**.

One of the earliest modeling studies was published by Green and colleagues in 2007 (26). The authors described 6 steps: identify the current panel size, estimate the daily visit rate per patient, fix the number of daily appointment slots, calculate the current overflow frequency, set the target overflow frequency, and compute the panel size based on the target flow frequency. In sample calculations, the authors presented the calculated panel size under assumptions about the number of daily appointment slots (20 or 24) and an overflow frequency of 5%, 10%, or 15%.

Another early model was published by Balasubramanian, who with colleagues has published variations of and improvements on it (25, 29). In the first such study, the authors used data from the primary care clinics at the Mayo Clinic to optimize panels on 2 measures of access (the average time a patient waits to see a provider and the number of a patient's visits that are to his or her own provider) and 1 measure of resource use (the additional capacity needed to be added for each period). The authors reported that their model only used age and sex for case-mix adjustment, and they planned to include more variables to better capture variations in demand. Subsequent versions of their model (27, 34) included more sophisticated case-mix adjustment, such as the presence of various chronic conditions, and resulted in better optimization when applied to panels of about 1000 patients in terms of smoothing out imbalances in demand and improving access. These results led the authors to conclude, "We have shown that case-mix is an important consideration in primary care." They noted that the effect these changes would have on quality of care remained to be evaluated. In the group's most recent study (31), they further attempted to refine their demand estimation by retrospectively quantifying patterns of face-to-face visits and care coordination events (emergency department visits). They were able to predict the number of weekly appointments needed for panel sizes of 1500 and 2000 patients. They also concluded, "As our results confirm . . . there is no one size fits all to the question [of what is the optimal panel size]. Each physician or care team is likely to have a different size depending on a variety of factors such as case mix, practice style, and available capacity."

Rajkomar and colleagues tried to improve the demand calculation by using electronic health record data to classify patients into phenotypes based on the number of their encounters (visits, telephone calls, electronic messaging, and care coordination) (28). This allowed them to weight panels on the basis of patient demand and complexity. They concluded that these phenotypes could predict future primary care use. With this information, panel sizes could be decreased for more complex patients or higher utilizers could be spread over different panels.

Altschuler and colleagues used a different method to calculate optimal panel size (24). Rather than taking existing data about real patients and prior demand for care, they estimated the work required to deliver primary care by using published estimates of the time needed to provide preventive care as defined by the U.S. Preventive Services Task Force grade A and B recommendations, the time needed to deliver care for 10 common chronic conditions, and the time needed to deliver acute care. They then calculated the number of patients to whom a primary care provider could deliver this care, given a certain number of hours worked per year. They did this calculation for 4 different assumptions of the amount of care that could be delegated to other providers, such as nurse practitioners, registered nurses, pharmacists, and health educators. In the model with no delegation, a provider could care for a panel of 983 patients, and in the model with the maximum amount of delegation, that number increased to 1947. Intermediate amounts of delegation produced numbers between these extremes. Of note, their calculations were based on an average case mix, and times per service were estimated and were not derived from time-motion studies.

It is important to note that the previously discussed study by Kamnetz and colleagues used modeling to improve optimal panel sizes by adding insurance status to the age and sex variables used for case-mix adjustments (10). Insurance status (Medicare, Medicaid, or other) was used as "a proxy for patient complexity." Because the study then assessed the effect of this change in a panel size calculation method in a pre–post fashion, it was categorized as a hypothesis-testing study and discussed in that section.

Certainty of Evidence

There is low-certainty evidence that increasing panel size has a modest negative association or no association with care that is effective and patient-centered; low-certainty evidence of variable associations with timely care; and very-low-certainty evidence on associations with safe, efficient, and equitable care and provider burnout. We judged the certainty of evidence as moderate that case-mix adjustment of panel size produces better access and that adjustment methods that include clinical conditions are better than adjustment using age and sex alone (Table).

DISCUSSION

Our principal finding is that the evidence about the association between panel size and aims of health care is surprisingly thin, given the importance of primary care panel size to all models of population-based care. The evidence consists of a handful of cross-sectional studies that assess associations of panel size with clinical quality, patient experience, access, and continuity and show variable, no, or negative associations between increasing panel size and these outcomes. One additional cross-sectional study found an association between larger panel size and physician burnout. These studies are limited by their design and therefore cannot support strong conclusions about increasing panel size causing any differences in outcomes. At best, the studies signal that there might be causal relation-

Table. Certainty of Evidence

Outcome	Studies, *n*	Limitations	Consistency	Direction of Effect	Overall Certainty of Evidence
Association of panel size with health outcomes					
Safety	0	NA	NA	NA	Very low
Efficacy (clinical quality)	3	Serious	Mostly consistent	No association or negative association of modest size	Low
Patient-centeredness	3	Serious	Inconsistent	No association or negative association of modest size	Low
Timeliness (access, including continuity)	8	Serious	Inconsistent	Variable	Low
Efficiency (including cost)	0	NA	NA	NA	Very low
Equity	0	NA	NA	NA	Very low
Provider burnout	1	Serious	NA	Increased burnout with panels with >1200 patients	Very low
Risk adjustment					
Access	5	Not serious	Consistent	Better optimization when panel sizes are adjusted for case mix	Moderate
Access	2	Not serious	Consistent	Risk adjustment that includes clinical conditions is better at optimizing access than risk adjustment with just age and sex	Moderate

NA = not applicable.

ships between larger panel size and worse clinical quality, worse patient experience, and provider burnout. The remainder of the evidence consists of a handful of studies that tried to model what should be an optimal panel size, with "optimal" defined exclusively by access. These modeling studies assumed that every patient added to a panel is going to receive care of equal quality and patient-centeredness regardless of the total panel size. The cross-sectional studies we identified suggest that this assumption may not be correct.

The modeling studies seem to show that simple models developed years ago can be improved. Not all patients require the same amount of time, and the risk adjustment methods that were tested vary from simple (adjusting for age and sex) to complex (adjusting for the number of health care conditions and the number of medications). The resources available to primary care providers, including the number of available rooms in which to see patients, the ability to delegate tasks to advanced practice providers, and the availability of registered nurse managers and other clinical staff, influence how many patients can be cared for. Implementing this kind of model-based approach to optimizing panel size requires data and analytics that may not be available to all primary care physician groups. Finally, since the early models were developed, there have been many changes in health care that affect the number of patients who can be cared for by providers. These include the rise of non–face-to-face visits, telehealth, secure messaging, and a greater load of information for primary care providers to process and manage.

Non–face-to-face tasks take up an increasing amount of clinician time. One study followed 57 physicians in 4 practices over approximately 1 month in 2015 (36) and found that for every hour of direct clinical time with patients, almost 2 additional hours are needed to complete electronic health record and desk work. Similarly, Farber and colleagues found that a full-time primary care provider would spend an extra 7.8 hours per week caring for their patient panel outside scheduled appointments (37). Doerr and colleagues found that primary care providers caring for a VA patient panel added 7.9 hours of work between visits per week (38). Finally, Baron determined that for his own panel of patients, over 1 year each patient generated an average of 2.0 face-to-face visits, 2.6 telephone calls, 1.3 prescription refills outside a visit, 1.8 e-mails, 2.1 laboratory reports, 1.2 imaging reports, and 1.5 reviews of a consultation (39).

The primary limitation of this review is the paucity of hypothesis-testing studies. Cross-sectional studies such as those we identified have limited ability to support causal conclusions. A second limitation is the possibility of publication bias, particularly for studies where panel size was not the primary explanatory variable but was tested as part of a multivariable regression analysis. Such studies have been shown to be prone to publication bias because investigators report results only for secondary variables that they consider "interesting." Third, although our searches were broad-based and used multiple databases, we can never be certain we have identified all relevant studies. Finally, all modeling studies have both strengths and limitations. They are inherently a simplification of reality and may omit important features of the problem. Therefore, models are best used to consider problems for which it is not feasible to empirically evaluate all alternatives and to inform rather than to make decisions based on their results.

In summary, the evidence about the association between primary care panel size and the aims of health care is modest at best. The few available studies provide a signal that increasing panel size may be associated with modest worsening of clinical quality and patient experience. Modeling studies support the idea that risk adjustment and practice-level variables influence the optimal panel size for patient access to care. Current recommendations about panel size are based more on historical experience than on evidence.

From West Los Angeles Veterans Affairs Medical Center and David Geffen School of Medicine, University of California, Los Angeles, Los Angeles, California (N.M.P.); West Los Angeles Veterans Affairs Medical Center, Los Angeles, California (E.A.A., S.M., I.M.M., M.M.B., J.M.S., P.G.S.); and Stanford University School of Medicine, Stanford, California (J.D.G.).

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Corresponding Author: Neil M. Paige, MD, MSHS, West Los Angeles Veterans Affairs Medical Center, 11301 Wilshire Boulevard, Los Angeles, CA 90073; e-mail, neil.paige@va.gov.

Current author addresses and author contributions are available at Annals.org.

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Current Author Addresses: Drs. Paige, Apaydin, Mak, Miake-Lye, and Shekelle; Ms. Begashaw; and Ms. Severin: West Los Angeles Veterans Affairs Medical Center, 11301 Wilshire Boulevard, Los Angeles, CA 90073.
Dr. Goldhaber-Fiebert: Stanford University School of Medicine, 615 Crothers Way, Encina Commons, Stanford, CA 94305-6006.

Author Contributions: Conception and design: N.M. Paige, E.A. Apaydin, P.G. Shekelle.
Analysis and interpretation of the data: N.M. Paige, E.A. Apaydin, J.D. Goldhaber-Fiebert, P.G. Shekelle.
Drafting of the article: N.M. Paige, E.A. Apaydin, J.D. Goldhaber-Fiebert, S. Mak, M.M. Begashaw, P.G. Shekelle.
Critical revision of the article for important intellectual content: N.M. Paige, E.A. Apaydin, J.D. Goldhaber-Fiebert, P.G. Shekelle.
Final approval of the article: N.M. Paige, E.A. Apaydin, J.D. Goldhaber-Fiebert, S. Mak, I.M. Miake-Lye, M.M. Begashaw, J.M. Severin, P.G. Shekelle.
Provision of study materials or patients: M.M. Begashaw.
Statistical expertise: J.D. Goldhaber-Fiebert.
Obtaining of funding: I.M. Miake-Lye, P.G. Shekelle.
Administrative, technical, or logistic support: S. Mak, I.M. Miake-Lye, M.M. Begashaw, J.M. Severin.
Collection and assembly of data: N.M. Paige, E.A. Apaydin, S. Mak, M.M. Begashaw, P.G. Shekelle.

Appendix: Description of Simulation Modeling Studies

Studies use predicted patient demand based on their own analyses of primary care provider data sets or published literature. Some predictions are the same on average for all patients, whereas others are conditional on age, sex, or other relevant clinical characteristics. Some studies allow for heterogeneity of demand across and within patient types as well as stochastic variation in demand. Of note, all estimates are based on purely observational analyses that do not consider change in demand as a function of changes in patient characteristics, panel size, or organizational features. The implication of this is that all studies assume that individual patient demand will not change as panel size and other organizational features are optimized or changed.

What Features of Supply Do Studies Consider?

Supply is typically considered as patient appointment slots with the implicit assumption generally that all appointments are of the same length. Some studies relax this assumption and allow for heterogeneity of appointment length and also consider complementary supply of non–face-to-face services.

What Outcomes Do Studies Consider?

Most studies assume that all or the vast majority of appointments should be offered on the day of the patient call, which is consistent with various articles by Berwick and colleagues (40). This implies that one of the main outcomes is ensuring that supply is equal to or greater than demand for appointments so that backlog is controllable. Some studies also consider the amount of time patients wait when they arrive at a crowded clinic to receive a same-day appointment.

No studies explicitly consider what services are delivered during appointments or via non–face-to-face means. Implicitly, this assumes that regardless of organization, all necessary or indicated services are delivered in the confines of each appointment. These modeling choices imply that the benefits gained and the harms averted by each incremental step toward satisfying patient demand are equal to all other steps.

Do Studies Consider Value?

Almost all studies match patient demand to supply without explicitly considering the costs of alternative panel sizes or other organizational structures. This supposes that meeting patient demand provides benefits that greatly outweigh the costs and that maximizing this outcome and/or closely related outcomes is therefore the same as maximizing value.

One study (29) explicitly attached costs and rewards (benefits) for the outcomes it considered as a function of panel size and combined these in an optimization framework. Presumably, the reward for fulfilling each demanded appointment (which, incidentally, is not dependent on patient type) was a monetization of the health gains and other benefits that come from a timely appointment.

What Approaches Do Studies Use to Conduct Their Analyses and Optimizations?

Some studies consider the total number of work hours that a primary care provider has available. They typically divide this into appointment sizes of a fixed length and then determine (given average demand per patient) how many patients could be in the panel. Other studies use various optimization techniques (such as analytic approximations or numerical optimization) to find panel sizes, case-mix changes, and other variables that satisfy the objectives they are trying to achieve (for example, a low chance that demanded appointments exceed the supply in a given day, or short in-clinic waiting times for patients).

Two additional articles we identified, 1 of which was from the gray literature, did not fit this categorization but are included here for completeness. One was a Microsoft PowerPoint presentation (32) that examined the effects of various factors when added to a "standard" panel size model calculator (probably similar to what was proposed by Murray and colleagues [41]) but is not about calculating optimal panel sizes per se. This presentation reports that patient acuity (or comorbidity or risk) "plays a small but perceptible role in observed panel size calculations" for the primary care provider. The other identified study assessed the relationship between overbooking and no-show rates (35). In this model, panel size was added as a control variable, given that "panel size . . . directly affects appointment delay." One conclusion of the model is that "there is a critical panel size range (with and without overbooking) in which both the patient show-up rate and the clinic's expected profit decreases as the panel size increases."

Appendix Table 1. Search Strategy

PubMed (inception to 3 October 2019)
Search strategy #1:
panel size*
Language:
English

PubMed (inception to 3 October 2019)
Search strategy #2:
capacity AND "primary care" AND (patient OR patients) AND (panel or panels)
OR
"patient concentration"
OR
"panel design"
OR
("patient panel" OR "patient panels") AND "primary care"
OR
"patient sample" AND "primary care"
OR
"Physician panel" OR "physician panels"
OR
"Physician workload" AND "primary care"
OR
"primary care" AND "practice list size"
OR
"primary care workload"
NOT
"panel size" OR "panel sizes"

Appendix Table 2. Citations for Excluded Studies

Not about panel size (*n* = 17)

Bailey SR, O'Malley JP, Gold R, et al. Diabetes care quality is highly correlated with patient panel characteristics. J Am Board Fam Med. 2013;26:669-79. [PMID: 24204063] doi:10.3122/jabfm.2013.06.130018

Carrier ER, Schneider E, Pham HH, et al. Association between quality of care and the sociodemographic composition of physicians' patient panels: a repeat cross-sectional analysis. J Gen Intern Med. 2011;26:987-94. [PMID: 21557031] doi:10.1007/s11606-011-1740-7

Cheung A, Stukel TA, Alter DA, et al. Primary care physician volume and quality of diabetes care: a population-based cohort study. Ann Intern Med. 2017;166:240-7. [PMID: 27951589] doi:10.7326/M16-1056

Devlin RA, Hogg W, Zhong J, et al. Practice size, financial sharing and quality of care. BMC Health Serv Res. 2013;13:446. [PMID: 24165413] doi:10.1186/1472-6963-13-446

Ellis R, Ash AS, Fernandez JG. "Good-enough" risk adjustment models for physician payment and performance assessment. Chicago: American Med Assoc; 2015. Accessed at https://edhub.ama-assn.org/steps-forward/module/2702760 on 21 October 2019.

Huntley A, Lasserson D, Wye L, et al. Which features of primary care affect unscheduled secondary care use? A systematic review. BMJ Open. 2014;4:e004746. [PMID: 24860000] doi:10.1136/bmjopen-2013-004746

Liu N, Ziya S. Panel size and overbooking decisions for appointment-based services under patient no-shows. Production and Operations Management. 2014;23:2209-23. doi:10.1111/poms.12200

Mandel D, Zimlichman E, Wartenfeld R, et al. Primary care clinic size and patient satisfaction in a military setting. Am J Med Qual. 2003;18:251-5. [PMID: 14717383]

Martin-Misener R, Donald F, Kilpatrick K, et al. Benchmarking for nurse practitioner patient panel size and comparative analysis of nurse practitioner pay scales: update of a scoping review. 2015. Accessed at https://fhs.mcmaster.ca/ccapnr/documents/np_panel_size_study_updated_scoping_review_report.pdf on 21 October 2019.

Marx R, Drennan MJ, Johnson EC, et al. Assessing and increasing patient panel size in the public sector. J Public Health Manag Pract. 2011;17:506-12. [PMID: 21964361] doi:10.1097/PHH.0b013e318211393c

Stempniewicz R, Cuddeback J. Primary care panel size: exploratory analysis. American Med Group Assoc; 2015. Accessed at www.amga.org/doc/Meetings/AC/2015/Handouts/Councils/CIO/Understanding%20the%20Structure%20of%20the%20Care%20Team%20from%20the%20Data.pdf on 21 October 2019.

Thomas JW, Grazier KL, Ward K. Economic profiling of primary care physicians: consistency among risk-adjusted measures. Health Serv Res. 2004;39:985-1003. [PMID: 15230938]

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Wang JS, Lin SY, Sheu WH, et al. Effects of patient volume on quality of outpatient diabetes care. Diabetes Res Clin Pract. 2009;84:e27-9. [PMID: 19269708] doi:10.1016/j.diabres.2009.02.010

Wensing M, van den Hombergh P, Akkermans R, et al. Physician workload in primary care: what is the optimal size of practices? A cross-sectional study. Health Policy. 2006;77:260-7. [PMID: 16129508]

Wensing M, Van den Hombergh P, Van Doremalen J, et al. General practitioners' workload associated to practice size rather than chronic care organisation. Health Policy. 2009;89:124-9. [PMID: 18599149] doi:10.1016/j.healthpol.2008.05.008

Zantinge EM, Verhaak PF, de Bakker DH, et al. The workload of general practitioners does not affect their awareness of patients' psychological problems. Patient Educ Couns. 2007;67:93-9. [PMID: 17382508]

Background (*n* = 16)

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Chung S, Eaton LJ, Luft HS. Standardizing primary care physician panels: is age and sex good enough? Am J Manag Care. 2012;18:e262-8. [PMID: 22823555]

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Hulshof PJH, Vanberkel PT, Boucherie RJ, et al. Analytical models to determine room requirements in outpatient clinics. OR Spectr. 2012;34:391-405. doi:10.1007/s00291-012-0287-2

Institute for Healthcare Improvement. Manage Panel Size and Scope of the Practice. Accessed at www.ihi.org/resources/Pages/Changes/ManagePanelSizeandScopeofthePractice.aspx on 21 October 2019.

Kivlahan C, Sinsky CA. Identifying the Optimal Panel Sizes for Primary Care Physicians. Chicago: American Med Assoc; 2018. Accessed at https://edhub.ama-assn.org/steps-forward/module/2702760 on 21 October 2019.

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Mayo-Smith MF, Dooley D. Primary Care Panels in the VA. 2017. Accessed at https://mdedge-files-live.s3.us-east-2.amazonaws.com/files/s3fs-public/Document/September-2017/021080047.pdf on 21 October 2019.

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U.S. Department of Veterans Affairs. Patient Centered Management Module (PCMM) for Primary Care. VHA Directive 1406. 20 June 2017. Accessed at www.va.gov/vhapublications/ViewPublication.asp?pub_ID=5430 on 21 October 2019.

Virani SS, Akeroyd JM, Ramsey DJ, et al. Health care resource utilization for outpatient cardiovascular disease and diabetes care delivery among advanced practice providers and physician providers in primary care. Popul Health Manag. 2018;21:209-16. [PMID: 28994631] doi:10.1089/pop.2017.0090

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Appendix Table 2—Continued

Tool kits (*n* = 8)

Tantau & Associates. Panels and Panel Equity. Advanced Access Information Series. Accessed at www.improvingchroniccare.org/downloads/3.2_panels_and_panel_equity.pdf on 21 October 2019.

The College of Family Physicians of Canada. Best Advice Guide: Panel Size. August 2011. Accessed at www.cfpc.ca/Best_Advice_Panel_Size on 21 October 2019.

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Safety Net Medical Home Initiative. Empanelment. Establishing Patient-Provider Relationships. May 2013. Accessed at www.safetynetmedicalhome.org/sites/default/files/Implementation-Guide-Empanelment.pdf on 21 October 2019.

Murray M, Davies M, Boushon B. Panel size: how many patients can one doctor manage? Fam Pract Manag. 2007;14:44-51. [PMID: 17458336]

Newman S, Nguyen D, Fisher T, et al. CP3 Population Health Toolkit. From volume to value: supporting care delivery transformation in the safety net. Oakland: Center for Care Innovations; 2017. Accessed at www.careinnovations.org/wp-content/uploads/CCI-Population-Health-Toolkit.pdf on 21 October 2019.

UMass Panel Design Spreadsheet. Accessed at https://people.umass.edu/hbalasub/PanelDesignSpreadsheet.xlsx on 21 October 2019.

No outcome of interest (*n* = 3)

Chien AT, Kyle MA, Peters AS, et al. Establishing teams: how does it change practice configuration, size, and composition? J Ambul Care Manage. 2018;41:146-55. [PMID: 29474254] doi:10.1097/JAC.0000000000000229

Dai M, Ingham RC, Peterson LE. Scope of practice and patient panel size of family physicians who work with nurse practitioners or physician assistants. Fam Med. 2019;51:311-8. [PMID: 30973618] doi:10.22454/FamMed.2019.438954

Poghosyan L, Liu J, Norful AA. Nurse practitioners as primary care providers with their own patient panels and organizational structures: a cross-sectional study. Int J Nurs Stud. 2017;74:1-7. [PMID: 28577459] doi:10.1016/j.ijnurstu.2017.05.004

Duplicate (*n* = 2)

Balasubramanian H, Denton B, Lin QM. Managing physician panels in primary care. In: Yih Y, ed. Handbook of Healthcare Delivery Systems. Boca Raton, FL: CRC Pr; 2011. Accessed at https://btdenton.engin.umich.edu/wp-content/uploads/sites/138/2014/07/Balasubramanian-Handbook-2009.pdf on 21 October 2019.

Mayo-Smith MF, Frisbee K, Harvey C, et al. Relationship of primary care panel size and healthcare outcomes in the VA. J Gen Intern Med. 2006;21:123.

Commentary (*n* = 1)

Keller AO. Does team-based task delegation affect patient panel size for primary care providers? J Am Acad Physician Assist. 2015;28.

Full text unavailable (*n* = 1)

Danforth KN, Slezak JM, Chen LH, et al. Risk factors for care-gaps in abnormal lab results follow-up within a large integrated health system. Diagnosis. 2017;4:eA118-eA119.

Nonsystematic review (*n* = 1)

Ahmadi-Javid A, Jalali Z, Klassen KJ. Outpatient appointment systems in healthcare: a review of optimization studies. Eur J Oper Res. 2017;258:3-34. doi:10.1016/j.ejor.2016.06.064

Appendix Table 3. Evidence Table for Hypothesis-Testing Studies

Study, Year (Reference)	Funding Source	Setting	Study Design	Objective	Panel Size, *n*	Other Factors	Outcomes*
Angstman et al, 2016 (7)	Department of Family Medicine, Mayo Clinic, Jacksonville, Florida	Department of Family Medicine at Mayo Clinic (Minnesota) 36 physicians; 3 sites; 9 care teams Clinical full-time equivalent: mean, 0.49 (SD, 0.13)	Cross-sectional	To assess the relationship among panel size and access, quality, patient satisfaction, and cost	Range adjusted for full-time equivalent: 1876–4828 Mean adjusted for full-time equivalent: 2959 (SD, 629)	CMS-HCC complexity score	Access: Negative Quality: Mixed Patient experience: Null Provider experience: NR
Dahrouge et al, 2016 (8)	Institute for Clinical Evaluative Sciences	Primary care practices in Ontario, Canada 4195 physicians Clinical full-time equivalent: NR	Cross-sectional	To determine the relationship between panel size and primary care quality indicators	Range: 1200–3900	Number of physicians; physician age; physician sex; indicator for foreign-trained physician; time since physician graduation; practice group size; practice rurality; number of patients; proportion of patients virtually rostered; patient age; patient sex; proportion of recent immigrant patients; patient rurality; patient income quintile; resource utilization band case-mix measure	Access: Positive Quality: Mixed Patient experience: NR Provider experience: NR
Francis et al, 2009 (9)	Department of Medicine at Southern Illinois University School of Medicine	Internal medicine residency program at Southern Illinois University 40 residents; number of patients NR Clinical full-time equivalent: NR	Cross-sectional	To determine whether resident panel size affects patient continuity	Mean: 54.7 (SD, 4.1)	Number of clinics attended by a resident; fixed effects for attending physician	Access: Negative Quality: NR Patient experience: NR Provider experience: NR
Helfrich et al, 2017 (16)	VA	Primary care providers (primary care physicians; nurse practitioners; physician assistants), nurse care managers, clinical associates, and administrative clerks from a national VA sample 4610 team members (1517 primary care providers, 1276 nurse care managers, 1164 clinical associates, 653 administrative clerks) Clinical full-time equivalent: NR	Cross-sectional	To study the association of burnout among primary care providers with staffing and workload of the teams	NR; 31.6% of panels had >1200 patients (overcapacity)	Indicator for team staffed to a 3:1 ratio; indicator for working on multiple teams; indicator for team turnover in last 12 months; average panel comorbidity; indicator for working extended hours; respondent occupation; duration of VA tenure; indicator for VA medical center (vs. CBOC); team random intercept; clinic random intercept; interaction between occupation and panel overcapacity	Access: NR Quality: NR Patient experience: NR Provider experience: Negative
Kamnetz et al, 2018 (10)	Clinical and Translational Science Award and University of Wisconsin Schools and Centers	Primary care physicians in the University of Wisconsin School of Medicine and Public Health, the University of Wisconsin Hospital and Clinics, and the University of Wisconsin Medical Foundation 112 physicians in 27 clinics Clinical full-time equivalent: NR	Observational; pre–post; retrospective	To describe how a utilization-based weighting system that accounts for patient complexity was developed and applied to primary care patient panels	Range: 1244–2315 before weighting, 949–2705 after weighting	Patient age, sex, and insurance type	Access: Mixed Quality: NR Patient experience: NR Provider experience: NR

Continued on following page

Appendix Table 3–Continued

Study, Year (Reference)	Funding Source	Setting	Study Design	Objective	Panel Size, *n*	Other Factors	Outcomes*
Katz et al, 2013 (14)	NR	VA primary care providers (unspecified specialty) Number of providers NR; 180 808 patients Clinical full-time equivalent: NR	Cross-sectional	To determine the association between primary care panel size and continuity of care	Median: 1178 (interquartile range, 982–1295)	Demographic characteristics; disability status; chronic medical and psychiatric conditions; number of primary care clinic visits; primary care full-time equivalent; primary care provider participation in a PACT learning collaborative; usual site of care	Access: Mixed Quality: NR Patient experience: NR Provider experience: NR
Margolius et al, 2018 (11)	NR	Primary care providers in MetroHealth system in northeastern Ohio (76% MDs) 114 providers; number of practices NR Clinical full-time equivalent: mean, 0.65 (SD, 0.27)	Cross-sectional	To investigate whether wait times for appointments were associated with panel size and number of clinical half-days in primary care	Mean: 1146 (SD, 618)	Full-time equivalent; clinicians/site	Access: Negative Quality: NR Patient experience: NR Provider experience: NR
Mittelstaedt et al, 2013 (12)	Department of Family Medicine and Department of Public Health and Preventive Medicine, Oregon Health & Science University	Primary care providers in Oregon Health & Science University Department of Family Medicine outpatient clinics (71% MDs) 63 providers; 4 clinics Half-day clinic sessions per month: mean, 16.83 (SD, 7.27)	Cross-sectional	To study the association between provider practice characteristics and interpersonal continuity	Range: 65–1377 Mean: 577.4 (SD, 315.8)	Clinic frequency (half-day clinic sessions per month); patient load (ratio of panel size to clinic frequency); years in practice; provider type; interaction of provider type and patient load	Access: Null Quality: NR Patient experience: NR Provider experience: NR
Mohr et al, 2013 (15)	VA	Primary care providers in VA (physician percentage NR) Number of providers NR; 222 clinics Clinical full-time equivalent: NR	Cross-sectional	To examine the effect of workload on patients' experiences of quality of care	NR; workload defined and reported as the ratio of actual panel size to optimal panel size	Patient age, sex, race, ethnicity, SF-12 score, and SHEP responses; clinic rurality; hospital/community-based setting; geographic region; teaching hospital affiliation; years in operation; full-time equivalent employees; and RNs per support staff	Access: Negative Quality: Negative Patient experience: Negative Provider experience: NR
Stefos et al, 2011 (13)	VA	Primary care providers in VA (71%–74% MDs) All VA practices (not otherwise specified) Clinical full-time equivalent: NR	NR	To assess how changes in primary care panel size are related to patient processes and satisfaction and to waiting time	Mean panel size: 1168–1206	Patient age, gender, insurance status, VA priority status, and clinical risk; clinical support staff; adjusted number of examination rooms; clinical full-time equivalent per primary care provider; available support staff; capital resources; patient satisfaction; distance in miles from VA facility; CBOC indicator	Access: Negative Quality: Negative Patient experience: Mixed Provider experience: NR

CBOC = community-based outpatient clinic; CMS = Centers for Medicare & Medicaid Services; HCC = Hierarchical Condition Categories; MD = medical doctor; NR = not reported; PACT = patient-aligned care team; RN = registered nurse; SF-12 = 12-Item Short Form Health Survey; SHEP = VA Survey of Healthcare Experiences of Patients; VA = Department of Veterans Affairs.
* "Positive" indicates a significant positive effect between the outcome and increasing panel size, "negative" indicates a significant negative association with increasing panel size, "mixed" indicates mixed effects, and "null" indicates no association. Effects were recoded as "positive" or "negative" regardless of original directionality to indicate how increasing panel size positively or negatively changes access, quality, or patient or provider experience. Predictors other than panel size are specified when appropriate.

Appendix Table 4. Evidence Table for Modeling Studies

Study, Year (Reference)	Predictors of Patient Demand	Demand Primary Estimates/Source*	Model Parameters†	Optimization/Technique	Other Notes
UCSF: Altschuler et al, 2012 (24)	Chronic conditions for chronic services time; unconditional averages for preventive and acute services	Based on Duke studies (1, 2, 42)	Demand stochastic? No Decision variables: Panel size; team organization Outcomes: Supply = demand Value: No explicit calculation	Accounting: The authors computed the maximum panel size that could be handled by a full-time equivalent primary care provider within a nonteam or various team organizations given average appointment time demand by chronic condition type, prevalence of chronic conditions, average acute appointment time, average time to provide preventive services, and average percentage of time for these services that could be offloaded from the primary care provider under various team models.	Assumes an average U.S. patient case mix; discussion mentions VA and perhaps needing smaller panel sizes given the older patient population with more prevalent chronic conditions
UCSF: Rajkomar et al, 2016 (28)	Age, sex, prior year demand patterns, and others	UCSF patients receiving care from primary care providers within academic health system from 2013 to 2015	Demand stochastic? NA Decision variables: None Outcomes: None Value: None	Prediction only: Authors develop a relatively complex statistical model to predict patient demand for visits and other non–face-to-face services, which they use to reweight current panel sizes based on this predicted patient heterogeneity.	Authors split their data to have training data (70%) and test data (30%).
Mayo Clinic: Balasubramanian, 2007 (29)	Age, sex	Mayo Clinic primary care practice data from 2004 to 2006 (39 primary care provider panels)	Demand stochastic? Yes Decision variables: Panel size and case mix Outcomes: Appointment wait times; redirection to another primary care provider; daily appointment overage Value: Outcomes (all negative) are valued as costs, with total cost being minimized	Panel design genetic algorithm	Authors claim that they likely do better than Green and colleagues (see below) for situations where variance around predicted demand for patient categories is relatively high (i.e., when demand is hard to predict). Essentially, the authors state that stochastic surges in demand will occur and will not be absorbed well in panel sizes/appointment slots as suggested by Green and colleagues. This happens because the surges will happen more frequently than there is excess capacity to quickly absorb the backlog of demand. The backlog will then propagate and grow. Supply is also not very flexible because unused appointments from one day cannot be moved forward to another day's capacity.
Mayo Clinic: Balasubramanian et al, 2010 (25)	Age, sex, chronic conditions	Mayo Clinic primary care practice data from 2004 to 2006 (39 primary care provider panels)	Demand stochastic? Yes Decision variables: Panel size and case mix Outcomes: Appointment wait times; redirection to another primary care provider Value: Not stated, but seems to be a similar cost minimization for negative outcomes as in the 2007 article	Stochastic linear programming	Also considers increased panel sizes; authors' limitations section notes many of the behavioral responses around demand and supply and the potential importance of patient–primary care provider matching

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Appendix Table 4—Continued

Study, Year (Reference)	Predictors of Patient Demand	Demand Primary Estimates/Source*	Model Parameters†	Optimization/Technique	Other Notes
Mayo Clinic: Ozen and Balasubramanian, 2013 (27)	Chronic conditions	Mayo Clinic primary care practice data from 2004 to 2006 (39 primary care provider panels)	Demand stochastic? Yes Decision variables: Panel size and case mix Outcomes: Overflow frequency value NR	Integer nonlinear programming	Instead of specifying a tradeoff between primary care provider–patient continuity and total panel size, authors optimize without allowing redirection and show how many fewer patients can be empaneled if continuity is required. They also consider at what clinical capacity physicians are working and expected overflow.
Mayo Clinic: Rossi and Balasubramanian, 2018 (31)	No explicit predictors; statistical sampling based on empirical distribution of actual data	Medical Expenditure Panel Survey 2011	Demand stochastic? NA Decision variables: None Outcomes: None Value: None	Prediction only: Authors use a set of statistical sampling techniques on patient-level longitudinal data that predict weekly demand for various primary care provider office and nonoffice services that require primary care provider coordination and then suggest that normal primary care providers with panels of 2000 patients will struggle to meet demand.	The main extension from the prior work, aside from considering more broadly representative distributions of patient demand, is to jointly model expected demands on primary care provider time from appointments and from other types of encounters that demand primary care provider time for coordination.
Columbia University: Green et al, 2007 (26)	Unconditional average	Based on prior studies by practice type (adult primary care provider, pediatrician)	Demand stochastic? No Decision variables: Panel size; daily appointment slots Outcomes: Supply = demand; low frequency of overflow Value: No explicit calculation	Given assumptions about distribution of demanded appointments (binomial), number of available daily slots, and a suitably low targeted overflow fraction, authors compute a panel size for which demand is satisfied and the overflow fraction does not exceed the target.	Authors are examining an advanced-access model (patients should be able to get same-day appointments).
Florida: Zacharias and Armony, 2017 (30)	None (could in principle, but study is entirely mathematical/simulation)	None	Demand stochastic? Yes Decision variables: Panel size, daily appointment slots Outcomes: Appointments delivered; cost of delayed appointments; cost of patient waiting; overtime costs Value: Outcomes are combined and reward is maximized	Diffusion approximations and other techniques used to provide analytic solutions that are then illustrated in simulation	Authors allow for more patient behaviors, such as deciding not to use care when the appointment backlog is too large. They show that in their model, advanced access (same-day appointment offering) will generally be optimal. They have a small example applied to an MRI clinic to determine a panel size that the clinic could handle under assumptions about the relative costs and benefits of their outcomes.
Southern Florida: Zeng et al, 2013 (35)	None explicitly stated; parameters derived from actual data	Public mental health clinic at the Johns Hopkins Bayview Medical Center in Baltimore, Maryland	Demand stochastic? No Decision variables: Panel size, overbooking status Outcomes: Appointment delay; office delay; daily clinic profit; probability of patients showing up Value: Not stated	Prediction only	NA

MRI = magnetic resonance imaging; NA = not applicable; NR = not reported; UCSF = University of California, San Francisco; VA = Department of Veterans Affairs.
* What data or other methods were used to define how many and what types of appointments were sought per unit time? Were these estimates from data analyses by the authors themselves, or were they extracted from other studies or reports?
† "Demand stochastic" refers to whether the actual number of people seeking appointments each day was allowed to vary stochastically around the average/expected rate of demand for such appointments. This may be important because surge demand that exceeds appointment capacity can lead to overtime in order to maintain high proportions of same-day appointments or to backlogs that make subsequent demand for appointments on subsequent days harder to satisfy and therefore can compound.

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