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Modelling accessibility of adult neurology care in Australia, 2020–2034

Steve Simpson-Yap ,[1,2,3] Federico Frascoli,[4] Lucinda Harrison,[1] Charles Malpas,[1,5] James Burrell,[6] Nicholas Child,[7] Lauren P Giles,[8] Christian Lueck,[9] Merrilee Needham,[10] Benjamin Tsang,[11] Tomas Kalincik,[1,5] On behalf of the Australian & New Zealand Association of Neurologists Workforce Committee

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For numbered affiliations see end of article.

Correspondence to
Dr Steve Simpson-Yap; steve.simpsonyap@unimelb.edu.au

Professor Tomas Kalincik; tomas.kalincik@unimelb.edu.au

ABSTRACT

Introduction In 2015/2016, annual national expenditure on neurological conditions exceeded $A3 billion. However, a comprehensive study of the Australian neurological workforce and supply/demand dynamics has not previously been undertaken.

Methods Current neurological workforce was defined using neurologist survey and other sources. Workforce supply modelling used ordinary differential equations to simulate neurologist influx and attrition. Demand for neurology care was estimated by reference to literature regarding incidence and prevalence of selected conditions. Differences in supply versus demand for neurological workforce were calculated. Potential interventions to increase workforce were simulated and effects on supply versus demand estimated.

Results Modelling of the workforce from 2020 to 2034 predicted an increase in neurologist number from 620 to 896. We estimated a 2034 capacity of 638 024 Initial and 1 269 112 Review encounters annually, and deficits against demand estimated as 197 137 and 881 755, respectively. These deficits were proportionately greater in regional Australia, which has 31% of Australia's population (Australian Bureau of Statistics) but is served by only 4.1% of its neurologists as determined by our 2020 survey of Australia and New Zealand Association of Neurologists members. Nationally, simulated additions to the neurology workforce had some effect on the review encounter supply deficit (37.4%), but in Regional Australia, this impact was only 17.2%.

Interpretation Modelling of the neurologist workforce in Australia for 2020–2034 demonstrates a significant shortfall of supply relative to current and projected demand. Interventions to increase neurologist workforce may attenuate this shortfall but will not eliminate it. Thus, additional interventions are needed, including improved efficiency and additional use of support staff.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There is a shortfall in the capacity of the neurological care support structure to meet patient demand. This is anecdotally known in Australia but has not been quantitatively assessed previously.

WHAT THIS STUDY ADDS

⇒ This is the first study of the neurology workforce in Australia and its ability to meet estimated patient demand in 2020 and 2034, as well as under certain simulated scenarios.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ We show a significant insufficiency in the neurology care supply in Australia, this even worse in regional Australia. We show that merely adding additional neurologists, even were this possible with existing resources, is not projected to meet the capacity shortfall. Thus, additional methods, including improved efficiency for referral and care pathways, expansion of the neurology support workforce, and improvements in the ability to general practitioners to manage more basic neurological issues, are needed to meet the workforce capacity shortfall.

INTRODUCTION

In 2015–2016, the annual national expenditure on neurological conditions in Australia ($A3 billion) exceeded 2.6% of total healthcare expenditure,[1] increasing to 3.0% in 2018–2019.[2] Like much of the world, Australia suffers from long patient wait times for specialised neurological care, likely reflecting some deficiency in the capacity of its neurological workforce to meet demand. To address this situation, it would be helpful to model the current position and assess the impact of potential future interventions. Such modelling has been undertaken in other healthcare settings[3–9] but efforts to model the supply and demand of neurology workforces worldwide are few and varied. Kurtzke first quantified patient demand for neurological care in the USA in 1981.[10] Based on prevalence and incidence rate estimates of neurological conditions, prevalent need among 3.6% of the population for neurological care each year was estimated, alongside 0.6% of the population with an incident condition requiring neurological assessment. In Greater London in 1995–1996, MacDonald *et al* estimated new neurological disorders in 0.6% of the population and a lifetime prevalence in 6% of the population.[11] Building on a previous US study by Bradley,[12] Dall *et al* modelled neurology demand in the USA over 2012–2025, based on modelling of patient numbers for selected conditions needing neurological care,[13] finding persistent supply deficits. Simulated interventions, including increased neurologist workforce and delayed retirement, were unable to eliminate these shortfalls. Applying the prevalence and incidence statistics from the Kurtzke[10] and MacDonald *et al*[11] studies, Ranta *et al* modelled the neurology workforce in New Zealand over 2014–2016,[14] finding deficits in supply in all scenarios. Simulated interventions adding neurologists, increasing efficiency and adding neurological nursing specialists reduced the deficit, but none realised sustained elimination of the supply deficit.

There has never been a study of the neurological workforce in Australia. The Australia and New Zealand Association of Neurologists (ANZAN) established a Workforce Committee to estimate the current neurology workforce and its capacity to meet demand in Australia. Accordingly, we undertook a survey of ANZAN neurologist members and acquired other necessary data to estimate the neurologist workforce supply in Australia, nationally and in regional Australia, in 2020 and projected to 2034. We also simulated interventions to introduce additional neurologists to the workforce and modelled resultant impacts on the supply-demand dynamics.

METHODS

Estimation of neurology care demand

After updating the list of conditions requiring neurology care, updated prevalence and incidence estimates were derived from the literature. In addition, the fractions of patients with each condition, and typical consult frequencies for each condition, were used to estimate initial and review patient demand in 2020 and 2034 (online supplemental tables 1–2). Typical consultation durations for initial and review encounters were estimated for each condition, and then these were used to estimate the durational load. The frequencies and durations of clinic attendance were based on internal expert opinion by the ANZAN Workforce Committee. Supply durations for initial and review encounters were estimated as the mean values expected for the current epidemiology of neurological conditions.

To allow comparison with previous reports, we also estimated demand based on the Kurtzke-MacDonald statistics.[10 11]

Model of Australian neurology workforce

The total number of adult neurology consultants was derived from Royal Australian College of Physicians (RACP) Internal Membership Reports for 2019 and 2020. In order to undertake specialised neurology training to practice neurology in Australia, registration as a trainee with the RACP is required, with successful trainees are then invited to become Fellows of the RACP. Therefore, estimates based on the numbers of RACP fellows is comprehensive of neurologists in Australia. We estimated the numbers of active neurology RACP fellows working in Australia in adult neurology over 2012–2020 (online supplemental table 3). Cohort characteristics from the 2020 ANZAN survey are shown in online supplemental tables 5 and 6. We applied the proportions from the 2020 ANZAN survey of neurologists working in the last 12 months who were also working in the previous 5 years but not earlier than this (60.3%), and then those working earlier than 5 years' previously (39.7%), the former defining early-career and the latter mid/late-career neurologists. Adding to these, we used internal data provided by ANZAN for the number of active advanced trainees over 2017–2020. These figures were used to estimate numbers of early-career and mid-career/late-career neurologists and trainees.

According to the Australian Bureau of Statistics, the population in regional Australia is 31.0% of the national population[15]; however, the 2020 ANZAN survey found only 4.1% of neurologists reported primarily working in regional Australia. Accordingly, we applied this 4.1% proportion to estimate the number of neurologists in regional Australia in 2017–2020, this also used for estimates in 2034.

Forecasting neurology workforce to 2034

The modelling of neurologist career progression in Australia used the numbers of basic physician trainees, advanced neurology trainees, early-career neurologist consultants, mid-career/late-career neurology consultants and semiretired (figure 1, online supplemental table 4). Entering the system are medical students completing basic physician training (α) and practitioners immigrating to Australia (μ). Exiting the system are practitioners leaving neurology, retiring or emigrating (γ). The modelled transitions between states include the transition from basic physician to advanced neurology trainee (λ_m), from advanced neurology trainee to early-career neurologist (λ_t) and from early-career to mid-career/late-career neurologist (λ_e). Mid-career/late-career neurologists were allowed to transition to semiretired (s_1) and thence to retired (s_2).

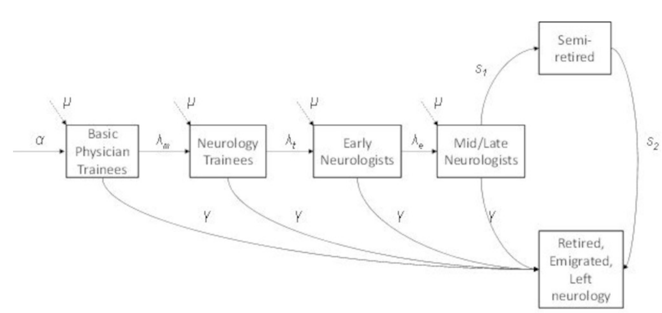

Figure 1 Neurologist career progression model used for estimating and projecting neurologist numbers.

$$\frac{dT}{dt} = \mu + \lambda_m - (\lambda_t + \gamma)T$$

$$\frac{dE}{dt} = \mu + \lambda_t T - (\lambda_e + \gamma)E$$

$$\frac{dL}{dt} = \lambda_e E - (\gamma + s)L$$

$$\frac{dS}{dt} = sL - \gamma S$$

Figure 2 Ordinary differential equations used for neurologist number projections.

A set of ordinary differential equations (ODEs) (figure 2) was used to estimate projected numbers of neurologists in national and regional Australia, using appropriate parameters and initial conditions. ODE analyses were conducted using Wolfram Mathematica for Windows V.12.1.1 (Wolfram Research, Champaign, USA). For simplicity, the set of ODEs considers a fixed, annual influx of neurologists from the basic physician trainees, captured by the parameter, λm. Also, given that the difference between the rates s_1 and s_2 is minimal, please note that we put $s_1=s_2=s$.

Estimating supply of outpatient neurology care

We estimated the number of clinic encounters by multiplying the number of active neurology practitioners working in adult neurology in Australia by the numbers of initial and review encounters per week and the mean number of weeks typically worked per year. We then estimated the durational supply by multiplying patient numbers by estimated typical consult duration, these increments defined as the weighted average of durations for each neurological condition from our updated review (online supplemental tables 1–2). This thus estimated durations of 46.9 min for initial and 23.6 min for review encounters.

Estimation of supply versus demand of neurology care

We estimated the gap between the supply of neurology outpatient care and clinical demand in two fashions. First, we subtracted the number of new and review encounters from the number of available encounters. Second, we preferentially allocated capacity to the 10% of initial encounters (representing urgent referrals), with the remaining capacity allocated to review encounters and then to remaining initial encounters. We also evaluated alternative proportions (20%, 30%, 40% and 50%) of initial encounters to be reviewed urgently (online supplemental table 11).

Simulated interventions

In addition to natural growth over 2022–2031, we evaluated adding an extra 5, 10 or 20 new neurologists per year nationally, and 2, 5 or 10 new neurologists per year in regional Australia.

RESULTS

Model of Australian neurology workforce

Based on the evolution of the Australian neurology workforce over the previous years, we estimated that there were 620 neurologists practising in adult neurology in Australia in 2020, this forecasted to increase to 896 in 2034 (figure 3). We then simulated interventions, adding an extra 5, 10 or 20 new neurologists per year over

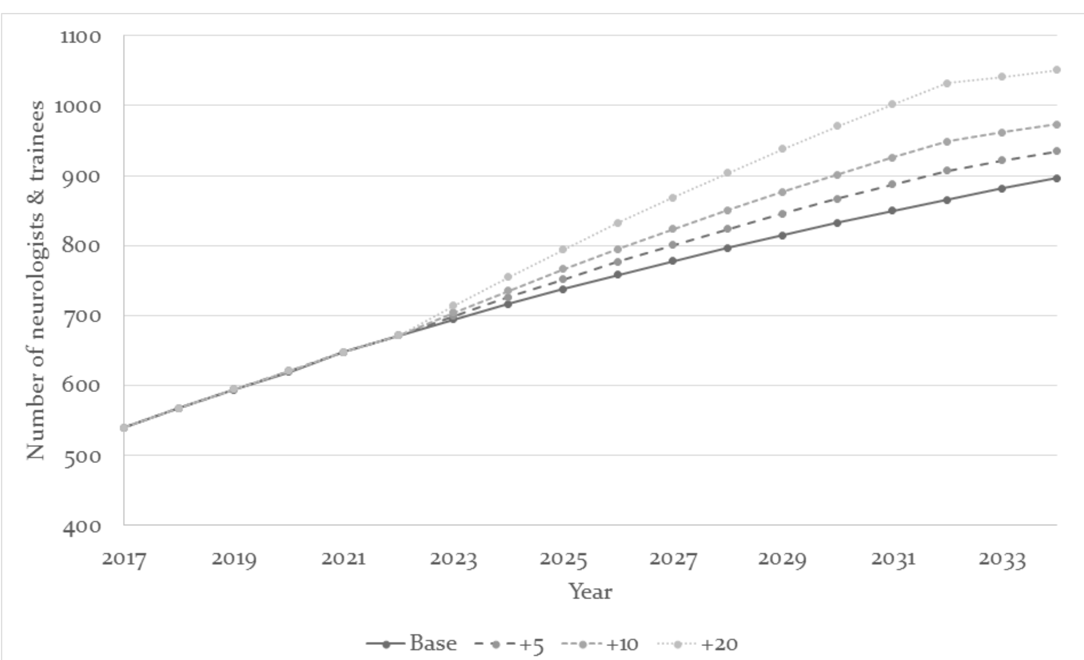

Figure 3 Projected numbers of neurologists in Australia, 2020–2034, including with simulated addition of extra 5, 10 and 20 neurologists per year over 2022–2031.

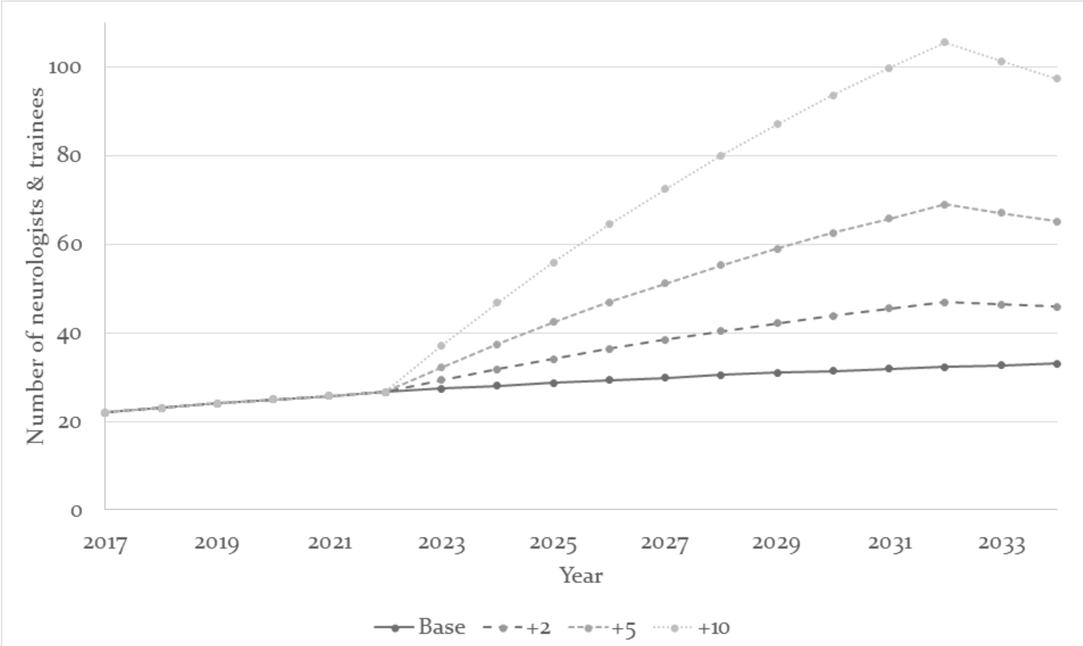

Figure 4 Projected numbers of neurologists in regional Australia, 2020–2034, including with simulated addition over 2022–2031 of an extra 2, 5 and 10 neurologists per year.

2022–2031, resulting in 935, 973 and 1051 neurologists, respectively, for Australia in 2034.

Regionally, there were 25 neurologists in 2020, forecasted to increase to 33 in 2034 (figure 4). On simulation of adding an extra 2, 5 and 10 new neurologists each year over 2022–2031, the numbers of neurologists in regional Australia in 2034 were estimated to be 46, 65 and 97, respectively.

Prevalence and incidence-based estimates of demand

In 2020, there was capacity for 441 490 initial encounters and 878 180 review encounters. This capacity was forecasted to increase to 638 024 initial and 1 269 112 review encounters in 2034.

In 2020, the capacity for initial encounters exceeded the demand by 269 391 encounters, with a large deficit of 1 322 516 review encounters, both persisting at 2034 (table 1). A more realistic allocation of neurological capacity, first allocated to 10% of the initial encounters with the remainder of capacity used to meet the need for review encounters, there were deficits of 154 889 initial encounters in 2020 and 197 137 in 2034, and of 898 236 review encounters in 2020 and 881 755 in 2034. Simulating the introduction of 50–200 new neurologists over 2022–2031, deficits in review encounter capacity were reduced by 37.4% to 551 838 (online supplemental table 7, figure 5).

In regional Australia in 2020, there was capacity for 17 802 initial and 35 411 review encounters. This capacity was forecasted to increase to 23 499 initial and 46 742 review encounters in 2034. In 2020, the deficits in supply in regional Australia reached 35 549 for initial encounters and 646 805 for review encounters, increasing in 2034 to 44 404 and 811 024, respectively. Applying preferential allocation of capacity to review encounters, initial and review encounter deficits were 48 016 and 634 357 in 2020 and 61 113 and 794 316 in 2034, respectively. Simulated addition of up to 100 extra neurologists to regional Australia over 2022–2031, the deficit in review encounters was reduced by 17.2% to 658 092 (online supplemental table 9, figure 6).

Estimation of durational supply and demand for neurological care

Taking into account consult durations for initial (46.9 min) and review (23.6 min) encounters, deficits were reduced but not eliminated. Applying the preferential allocation of capacity to review encounters, there was a deficit in capacity for initial encounters of 121 003 in 2020 and 154 008 in 2034; review capacity was short by 207 468 in 2020 and 111 667 in 2034 (table 2). By simulated introduction of 50–200 new neurologists over 2022–2031, the deficit in review encounters could be eliminated only by the maximum simulated addition (online supplemental table 8).

In regional Australia, deficits persisted in 2020 and 2034 for both initial (37 511 and 47 743) and review (249 544 and 305 768) encounters. On simulating the introduction of up to 20–100 additional neurologists to regional Australia over 2022–2031, the deficit in review encounters could be reduced by up to 23.2% to 234 868 (online supplemental table 10).

Kurtzke-MacDonald estimates of demand

The numbers of people estimated to need specialty neurological care were underestimated when based on the estimates by Kurtzke[10] and MacDonald *et al.*[11] However, we include them here for comparison with previous studies.

Table 1 Neurology encounter supply and demand estimation, national and regional, 2020–2034, updated incidence and prevalence-based demand estimates

	Australia		Regional Australia	
	2020	2034	2020	2034
Supply of neurological care				
Neurologists	620	896	25	33
Weeks/year	43	43	43	43
Initial encounters per week (2.75 per clinic)*	16.56	16.56	16.56	16.56
Review encounters per week (5.49 per clinic)*	32.94	32.94	32.94	32.94
Initial encounters/year†	441 489.60	638 023.68	17 802.00	23 498.64
Review encounters/year‡	878 180.40	1 269 112.32	35 410.50	46 741.86
Demand for neurological care§				
Initial encounters/year	172 099.08	219 041.47	53 350.71	67 902.86
Review encounters/year	2 200 696.20	2 766 987.22	682 215.82	857 766.04
Difference between supply and demand of neurological care§				
Initial encounters/year	Demand fully met	Demand fully met	–35 548.71	–44 404.22
Review encounters/year	–1 322 515.80	–1 497 874.90	–646 805.32	–811 024.18
Supply versus demand based on Australia national disease-specific patient counts§, 10% Initial allocation first, then remaining capacity to review				
Initial encounters/year	–154 889.17	–197 137.32	–48 015.64	–61 112.57
Review encounters/year	–898 236.11	–881 755.37	–634 356.88	–794 315.82

*Initial and review encounter numbers derived from 2020 ANZAN Member Survey.
†Capacity for initial encounters estimated as: number of neurologists×FTE fraction×weeks/year×# initial patients per week.
‡Capacity for review encounters estimated as: number of neurologists×FTE fraction×weeks/year×# review patients per week.
§Estimated initial and review encounter load based on disease-specific encounter counts as in online supplemental table 1.
ANZAN, Australia and New Zealand Association of Neurologists; FTE, Full time equivalent.

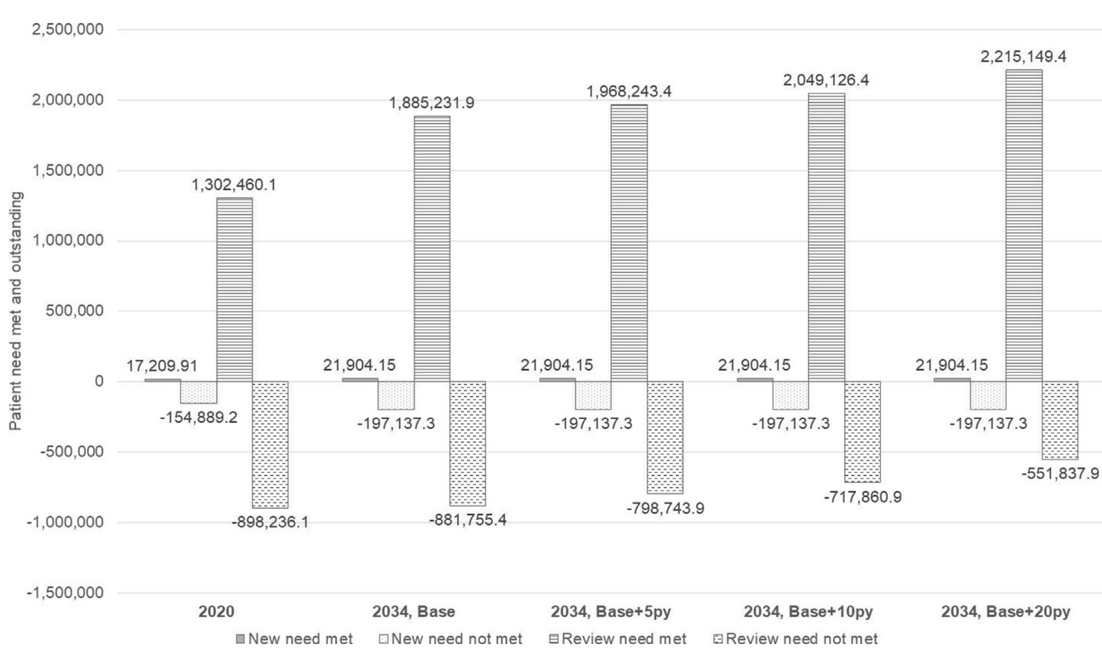

Figure 5 Estimation of supply and demand of neurological care in Australia, 2020–2034, updated prevalence and incidence-based demand estimates, preferential capacity allocation to review encounters.

According to the Kurtzke-McDonald estimations, patient capacity for initial encounters would exceed demand by 277 395 in 2020 and 441 729 in 2034, while for review encounters there would be a deficit of 105 893 in 2020 but a surfeit of 91 340 in 2034. In regional Australia, the capacity for initial encounters would fall short of demand by 33 070 in 2020 and 37 353 in 2034, while for review

Table 2 Estimation of durational supply and demand for neurological care, national and regional, 2020–2034, updated incidence and prevalence-based demand estimates

	Australia		Regional Australia	
	2020	2034	2020	2034
Supply of neurological care				
Neurologists	620	896	25	33
Weeks/year	43	43	43	43
Initial encounters per week (2.75 per clinic)*	16.56	16.56	16.56	16.56
Review encounters per week (5.49 per clinic)*	32.94	32.94	32.94	32.94
Initial encounters/year†	441 489.60	638 023.68	17 802.00	23 498.64
Review encounters/year§	878 180.40	1,269,112.32	35 410.50	46 741.86
Durational supply of neurological care, hours (60 min per new, 30 min per review)				
Initial encounters/year†	344 361.89	497 658.47	17 802.00	23 498.64
Review encounters/year§	342 490.36	494 953.80	17 705.25	23 370.93
Durational demand for neurological care‡				
Initial encounters/year	134 447.29	171 878.64	13 885.56	18 328.94
Review encounters/year	880 875.74	1 087 167.43	13 810.10	18 229.33
Supply vs 1-year average durational demand based on Australia national disease-specific patient counts‡				
Initial encounters/year	Demand fully met	Demand fully met	–27 793.10	–34 718.15
Review encounters/year	–538 385.39	–592 213.62	–259 261.39	–318 792.58
Supply vs 1-year average durational demand based on Australia national disease-specific patient counts‡, 10% Initial allocation first, then remaining capacity to review				
Initial encounters/year	–121 002.56	–154 007.67	–37 510.79	–47 742.38
Review encounters/year	–207 468.23	–111 667.12	–249 543.69	–305 768.35

*Initial and review encounter numbers derived from 2020 ANZAN Member Survey.
†Capacity for initial encounters estimated as: number of neurologists×FTE fraction×weeks/year×# initial encounters per week.
‡Estimated initial and review encounter load based on disease-specific encounter counts as in online supplemental table 1.
§Capacity for review encounters estimated as: number of neurologists×FTE fraction×weeks/year×# review encounters per week.
ANZAN, Australia and New Zealand Association of Neurologists; FTE, Full time equivalent.

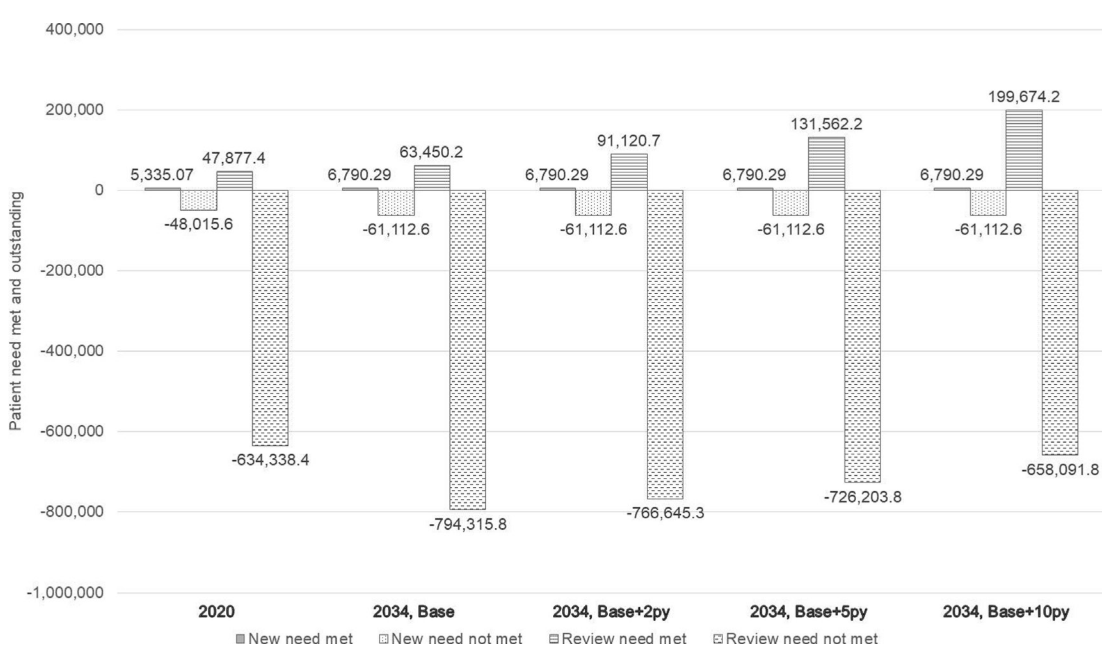

Figure 6 Estimation of supply and demand of neurological care in regional Australia, 2020–2034, updated incidence and prevalence-based estimates of demand, preferential capacity allocation to review encounters.

encounters the deficits would be 269 821 in 2020 and 318 367 in 2034.

DISCUSSION

Here, we have undertaken the first assessment of the Australian neurologist workforce, demonstrating a marked shortfall in the ability of the present and projected workforce to meet patient demand for specialist outpatient neurology care. By multiple methodological approaches, we consistently demonstrated that the neurological workforce was insufficient to meet both demand for initial and follow-up outpatient care. These shortfalls and their projections exceeded critical levels in regional Australia. In the most plausible models, consistent subsidised increase in the number of neurologists mitigated but did not eliminate the deficits at either national or regional levels. These results indicate that unless more holistic efforts (incorporating increases to the workforce alongside improvements in systems of care) to improve neurology care in Australia are undertaken, the shortfalls in the availability of neurology care in Australia are likely to persist.

These results are in keeping with modelling in New Zealand.[14] There, only a combination of increases to the number of neurologists and neurology support staff plus improved efficiency were sufficient to meet the demand of neurology care. Similarly, a study of the neurologist workforce in the USA[13] found consistent deficits, which simulated interventions increasing neurologist numbers through greater recruitment and retention had only minor effects on. These studies alongside our own indicate that efforts to meet the demand of neurology care depends on but is not limited to increases in neurologist number. Ranta *et al* proposed more comprehensive changes to the neurology system of care, including increases in the number of neurologists, improved retention of existing neurologists, and increases in the number of neurology nurse specialists, as well as greater use of telehealth for regional/rural patients to access care, and enhancements to the communication interface between specialists and general practitioners, including electronic decision-support tools.[14] The latter point would benefit from enhanced education modules for general practitioners, to support their diagnosis and management of some of the more common conditions, such as epilepsy, migraine and functional neurological disorders.[12] Efforts to address the regional deficits may require focused interventions such as recruitment and retention incentives. We explored such retention in our simulated interventions but further exploration of these dynamics is needed.

Strengths and limitations

We have considered the Kurtzke-MacDonald metrics of neurology demand for neurology care,[10,11] allowing comparability with previous work in our geographical region.[14] In addition to this, we have improved on these metrics of demand of neurology care, conducting an updated review of the literature to estimate the prevalence and incidence of conditions likely requiring neurological care, as well as considering consult frequency and duration. However, this approach is limited in various respects. Our estimates are based on the estimated numbers of patients with such conditions, but not necessarily the numbers who are seeking care. Also, the frequencies and durations of clinic attendance were based on internal expert opinion by the ANZAN Workforce Committee rather than epidemiological data. For estimating durational load, though our estimates of demand were condition-specific, supply durations for initial and review encounters were estimated as the mean values expected for the current epidemiology of neurological conditions.

Our assessments of the distribution of patients with neurological conditions in regional Australia are proportional estimates based on Census data from the Australian Bureau of Statistics. Our projections regarding potential interventions to add neurologists in regional Australia may be optimistic in presumed longevity. Nonetheless, even with this overestimation of projected capacity, there were still persistent deficits, suggesting that our estimates of deficits in capacity are likely underestimates.

Our estimates of neurologist number may overestimate the workforce capacity since they include trainees. While trainees are semiautonomous in clinical settings, their capacity to provide care relies on consultation with neurology specialists. Despite this potential overestimation, we still see deficits in the supply of neurology outpatient care, so our estimates of deficit may underestimate the reality.

This project did not stratify the supply-demand balance by specialty areas, nor did it explore the distribution of neurologists across the career stages and by sex. These questions would warrant dedicated models in the future.

The impacts of short-term/long-term leave, immigration/emigration and partial/complete retirement on the available workforce were only partially captured in our analyses. Further exploration of these phenomena would be useful.

CONCLUSIONS

We have shown that the current access to specialist neurology care in Australia is suboptimal, nationally and especially in regional Australia. The projected trends indicate that the gap between the supply and the demand of neurology care will further widen over the coming years. This gap can be mitigated by sustainable increases in neurological workforce, but this is likely insufficient alone. Thus, while efforts to expand the workforce should be pursued, including investment in the neurology training programme and subsidy of more neurology positions, especially in regional Australia, this should be undertaken in concert with other initiatives, including (1) improvements in the efficiency of referral and care pathways; (2) expansion of the neurology support workforce, including specialist neurology nurses, nurse practitioners and administrative support staff and (3) improvements in the training of general practitioners to diagnose and manage uncomplicated and common neurological conditions, ideally supplemented by evidenced based electronic decision support aids. These initiatives taken together will better enable the available outpatient neurology services to meet the patient demand.

Author affiliations
[1]CORe, Department of Medicine, The University of Melbourne, Melbourne, Victoria, Australia
[2]Neuroepidemiology Unit, Melbourne School of Population & Global Health, The University of Melbourne, Carlton, VIC, Australia
[3]Menzies Institute for Medical Research, University of Tasmania, Hobart, TAS, Australia
[4]Department of Mathematics Computing, and Engineering Technologies, Swinburne University of Technology, Hawthorn, Victoria, Australia
[5]Neuroimmunology Centre, Department of Neurology, The Royal Melbourne Hospital, Parkville, Victoria, Australia
[6]Concord Clinical School, Faculty of Medicine and Health, The University of Sydney, Sydney, New South Wales, Australia
[7]Neurology North Shore, Auckland, New Zealand
[8]Department of Neurology, Launceston General Hospital, Launceston, Tasmania, Australia
[9]School of Medicine and Psychology, Australian National University, Canberra, Australian Capital Territory, Australia
[10]Centre for Neuromuscular and Neurological Disorders, Perron Institute for Neurological and Translational Science, University of Western Australia, Nedlands, Western Australia, Australia
[11]Neurology, Sunshine Coast University Hospital, Sunshine Coast, Queensland, Australia

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Contributors SS-Y undertook all analyses aside from ODE and primary manuscript drafting. FF undertook ODE analyses. JB, NC, LPG, CL, MN, BT and TK were on the expert consultation committee and provided critical revision. LH undertook work on an earlier iteration of this project and provided critical revision. CM provided critical revision and expert guidance. TK acts as guarantor for this work, and accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Patient consent for publication Not applicable.

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Provenance and peer review Not commissioned; externally peer reviewed.

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ORCID iD
Steve Simpson-Yap http://orcid.org/0000-0001-6521-3056

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Correction: *Modelling accessibility of adult neurology care in Australia, 2020–2034*

Simpson-Yap S, Frascoli F, Harrison L On behalf of the Australian & New Zealand Association of Neurologists Workforce Committee, *et al*. Modelling accessibility of adult neurology care in Australia, 2020–2034. *BMJ Neurol Open* 2023;5:e000407

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Appendices

Supplemental Table 1. Estimated new and review patient load, Australia, 2020.

	Initial patients					Review patients					
	Prop. Likely to see neurologist	Initial encounter duration, min.	Incidence rate per 100,000 person-years	Initial case load	Initial case durational load, hours	Prop. likely to see neurologist	Review encounter frequency	Review encounter duration, min.	Prevalence per 100,000 persons	Review case load	Review case duration load, hours
Autoimmune encephalitis	30%	60	0.80[1]	61.69	61.69	30%	3	30	13.70[1]	3,169.38	554.64
Nervous system cancers	60%	60	7.20[2]	1,110.44	1,110.44						
Traumatic brain injury	5%	60	939.00[3]	12,068.31	12,068.31	5%	1	30	12111.08[4]	155,655.31	77,827.66

CIDP and chronic neuropathies	100%	40	0.33[5]	84.83	56.55	100%	2	20	2.81[5]	1,444.60	481.53
Encephalitis, infectious	5%	60	5.00[2]	64.26	64.26	0%					
Epilepsy	100%	40	61.44[6]	15,792.91	10,528.61	50%	2	20	638.00[6]	163,995.37	54,665.12
Functional neurological disorders	100%	60	29.50[7]	7,582.86	7,582.86	20%	2	30	37.20[7]	3,824.84	286.86
Guillain-Barre	100%	40	1.11[8]	285.32	190.21	50%	2	20	1.90[9]	488.39	24.42
Migraine	15%	40	810.00[10]	31,231.09	20,820.73	15%	2	20	15000.00[11]	1,156,707.1	385,569.05
Motor neurone disease	100%	40	0.78[12]	200.50	133.66	100%	3	30	4.50[12]	3,470.12	1,735.06

Multiple sclerosis and neuroimmunology	100%	60	3.30[2]	848.25	848.25	100%	2	30	103.70[13]	53,311.35	26,655.67
Myasthenia gravis	100%	60	0.53[14]	136.23	136.23	100%	2	30	7.77[14]	3,994.50	1,997.25
Myopathies, inflammatory	50%	60	0.80[15]	102.56	102.56	0%					
Neurocognitive disorders	20%	60	923.06[16] (60+yo)	10,615.09	10,615.09	10%	1	30	13402.35[17] (65+yo)	57,577.14	28,788.57
Optic neuritis	50%	60	3.70[18]	475.54	475.54	0%					
Pain (neuropathic, vertebrogenic)	5%	40	820.00[19]	10,538.89	7,025.92	5%	2	20	9,800.00[20]	2,519,051.09	83,968.37

Parkinson's disease & Movement disorders	90%	60	13.43 [21]	3,106.92	3,106.92	90%	2	60	106.28 [21]	124,574.40	124,574.40
Peripheral nerve injuries	50%	60	13.90 [22]	1,786.47	1,786.47	0%					
Peripheral neuropathy/ neuritis	10%	60	790.00 [23]	20,306.64	20,306.64	10%	2	30	2360.00 [23 24]	121,325.73	60,662.86
Sleep disorders						5%	1	20	6947.17 [25]	89,287.18	29,762.39
Obstructive sleep apnoea	5%	40	139.20 [26]	1,789.04	1,192.69						
Insomnia	5%	40	1842.95 [27] (35+yo)	12,933.84	8,622.56						

Spinal cord injury	5%	60	1.45[28]	372.72	18.64	0%					
Stroke	95%	40	159.00[29]	38,762.54	36,824.41	5%	1	20	1316.30[29]	2,043.50	681.17
Transverse myelitis	95%	60	3.10[30]	796.84	757.00	0%					
Trigeminal neuralgia	50%	40	9.90[31]	2,544.76	1,272.38	50%	4	20	9.90[32]	7,922.16	2,640.72
Total				172,099.08	134,447.29					2,200,696.20	880,875.74
Abbreviations: CIDP= Chronic inflammatory demyelinating											

polyradiculoneuro pathy.											

Supplemental Table 2. Estimated new and review patient load, Australia, 2034. This estimate is based on the current epidemiological data, projected for the forecasted population growth.

	Initial patients					Review patients					
	Prop. likely see neurologist	Consult duration, min.	Incidence rate	Initial case load	Initial case durational load, hours	Prop. likely see neurologist	Consult frequency	Consult duration, min.	Prevalence	Review case load	Review case duration load, hours
Autoimmune encephalitis	30%	60	0.80[1]	78.52	78.52	30%	3	30	13.70[1]	4,033.87	705.93
Nervous system cancers	60%	60	7.20[2]	1,413.33	1,413.33						0.00
Traumatic brain injury	5%	60	939.00[3]	15,360.11	15,360.11	5%	1	30	12111.08[4]	198,112.46	99,056.23

CIDP and chronic neuropathies	100%	40	0.33[5]	107.96	71.97	100%	2	20	2.81[5]	1,838.63	612.88
Encephalitis, infectious	5%	60	5.00[2]	81.79	81.79	0%					
Epilepsy	100%	40	61.44[6]	20,100.64	13,400.43	50%	2	20	638.00[6]	208,727.38	69,575.79
Functional neurological disorders	100%	60	29.50[7]	9,651.19	9,651.19	20%	2	30	37.20[7]	4,868.12	365.11
Guillain-Barre	100%	40	1.11[8]	363.15	242.10	50%	2	20	1.90[9]	621.60	31.08
Migraine	15%	40	810.00[10]	39,749.81	26,499.87	15%	2	20	15000.00[11]	1,472,215.05	490,738.35
Motor neurone disease	100%	40	0.78[12]	255.18	170.12	100%	3	30	4.50[12]	4,416.65	2,208.32

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Multiple sclerosis and neuroimmunol.	100%	60	3.30[2]	1,079.62	1,079.62	100%	2	30	103.70[13]	67,852.76	33,926.38
Myaesthenia gravis	100%	60	0.53[14]	173.39	173.39	100%	2	30	7.77[14]	5,084.05	2,542.02
Myopathies, inflammatory	50%	60	0.80[15]	130.54	130.54	0%					
Neurocognitive disorders	20%	60	923.06[16] (60+yo)	13,510.48	13,510.48	10%	1	30	13402.35[17] (65+yo)	73,282.11	36,641.05
Optic neuritis	50%	60	3.70[18]	605.24	605.24	0%					
Pain (neuropathic, vertebrogenic)	5%	40	820.00[19]	13,413.51	8,942.34	5%	2	20	9,800.00[20]	320,615.72	106,871.91

Parkinson's & Movement disorders	90%	60	13.43[21]	3,954.37	3,954.37	90%	2	60	106.28[21]	124,574.40	124,574.40
Peripheral nerve injuries	50%	60	13.90[22]	2,273.75	2,273.75	0%					
Peripheral neuropathy/ neuritis	10%	60	790.00[23]	25,845.55	25,845.55	10%	2	30	2360.00[23 24]	154,419.00	77,209.50
Sleep disorders						5%	1	20	6947.17[25]	113,641.49	37,880.50
Obstructive sleep apnoea	5%	40	139.20[26]	2,277.03	1,518.02						
Insomnia	5%	40	1842.95[27] (35+yo)	16,461.72	10,974.48						

Spinal cord injury	5%	60	1.45[28]	23.72	23.72	0%					
Stroke	95%	40	159.00[29]	49,417.07	32,944.71	5%	1	20	1316.30[29]	2,600.90	866.97
Transverse myelitis	95%	60	3.10[30]	963.48	963.48	0%					
Trigeminal neuralgia	50%	40	9.90[31]	1,619.44	1,079.62	50%	4	20	9.90[32]	10,083.04	3,361.01
Total				219,041.47	171,119.63					2,766,987.22	1,087,167.43
Abbreviations: CIDP= Chronic inflammatory demyelinating polyradiculoneuropathy.											

Supplemental Table 3. Estimating number of Active Neurology Consultant Fellows of the RACP, practicing in Adult Neurology in Australia from RACP Internal Membership Reports.

	2020[33]	2019[34]
RACP Members	27,843	26,761
In Australia	23,303 (83.7%)	22,330 (83.4%)
RACP Fellows	18,863 (67.8%)	18,071 (67.5%)
Active RACP Fellows	17,160 (61.6%) (91.0% of Fellows)	16,435 (61.4%) (91.0% of Fellows)
Australian RACP Fellows	15,641 (82.9%)	14,919 (66.8%)
Australian Active RACP Fellows	14,436 (51.8%)	13,774 (51.5%)
Australian Active RACP Fellows	14,436	13,774
Major Urban	12,685 (87.9%)	12,133 (88.1%)
Inner Regional	1,235 (8.6%)	1,150 (8.3%)
Outer Regional	445 (3.1%)	424 (3.1%)

Remote	70 (0.5%)	65 (0.5%)
Neurology	960	901
Adult Neurology practitioners (including non-fellows)	852 (88.8%)	800 (88.8%)
Neurology Fellows	756 (78.8%)	710 (78.8%)
Neurology RACP Fellows x % in Australia x % Active x % Adult Neurology	756x83.7%x91.0%x88.8%	710x83.4%x91.0x88.8%
Number of Active, Neurology RACP Fellows working in Australia who work in Adult Neurology (does not include neurology trainees)	**511**	**479**

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Supplemental Table 4. Allocation of model parameters based on data from MBA, RACP, Medical Deans ANZ Student Statistics, and ANZAN survey.

	μ	α	M(0)	λ_m	T(0)	λ_t	E(0)	λ_e	L(0)	s_1	S(0)	$s_2 + \gamma$	Total neurologists
2020	0.38	3,637	4,155	0.44	106	47	208	35	299	3.5 (0.9% PY)	4	0.46	617
2019	0.53	3,693	3,996	0	96	47	195		280		4	0.40	575
2018	0.48	3,475	4,052	2	90	45	193		277		3		564
2017		3,569	3,569		83	22	187		267		3		540
2016		3,547				1							422
2015		3,437				25							421

Number of Advanced Physician Trainees in neurology (T); Number of Early-Career neurology consultants (E): from the 2020 ANZAN survey; Number of Mid/Late-Career neurology consultants (L): from the 2020 ANZAN survey; Number of semi-retired (S): From the 2020 ANZAN survey; Immigration (μ): μ is derived from data from the Medical Board of Australia international medical graduate applications; Rate of Basic Physician Trainees admitted into Advanced Neurology Trainees (λ_m): from ANZAN records; Rate of Retirement: from RACP annual reports; Rates of transition from Advanced Neurology Trainee to Early-Career Neurologist (λ_t) and from Early-Career Neurologist to Mid/Late-Career Neurologist (λ_e) are dynamically estimated within the

function by the Total Neurology Consultant numbers and the values of the other model components; Rate of conversion from semi-retired to retired (s2) and rate of conversion to retired, emigrated, and left neurology (γ).

Supplemental Table 5. ANZAN survey respondent characteristics.

	n (%)	
	Total survey sample (n=738)	Australian, Active, Working in last 12 months, Works with adults (n=577)
Sex		
Male	472 (64.0%)	370 (64.1%)
Female	265 (35.9%)	206 (35.7%)
Unspecified	1 (0.1%)	1 (0.2%)

ANZAN member		
No Yes	6 (0.8%) 732 (99.2%)	5 (0.9%) 572 (99.1%)
Working status		
Active TNIP Semi-retired Retired	714 (96.8%) 9 (1.2%) 13 (1.8%) 2 (0.3%)	577 (100%)
Country of secondary school		
Australia New Zealand Other (Missing)	236 (68.2%) 30 (8.7%) 80 (23.1%) (392 (53.1%))	214 (72.8%) 9 (3.1%) 71 (24.2%) (283 (49.1%))
Country of medical school		

Australia	378 (70.9%)	332 (76.2%)
New Zealand	42 (7.9%)	8 (1.8%)
Other	113 (21.2%)	96 (22.0%)
(Missing)	(205 (27.8%))	(141 (24.4%))
Country of specialist training		
Australia	362 (81.0%)	325 (87.8%)
New Zealand	25 (5.6%)	3 (0.8%)
Other	60 (13.4%)	42 (11.4%)
(Missing)	(291 (39.4%))	(207 (35.9%))
Country of current work		
Australia	649 (879%)	577 (100%)
New Zealand	58 (7.9%)	
Other	31 (4.2%)	

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Adult/paediatric neurology		
Neither	29 (3.9%)	14 (2.4%)
Adult only	692 (93.8%)	558 (96.7%)
Paediatric only	11 (1.5%)	0 (0%)
Both	6 (0.8%)	5 (0.9%)
Advanced physician trainee?		
No	565 (76.6%)	447 (77.5%)
Yes	173 (23.4%)	130 (22.5%)
	Mean (SD; range)	
Age (missing 2)	44.68 (12.43; 20-85)	44.26 (11.96; 26-84)

Abbreviations: ANZAN = Australia New Zealand Association of Neurologists; TNIP = Temporarily not in practice.

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Supplemental Table 6. Neurology specialisations and mean patient numbers/FTE fractions from 2020 ANZAN survey, restricted to 577 respondents who were active, adult neurologists, working in Australia.

	Number of practitioners who work in a neurological specialty (out of 577)?	Number of NEW encounters per clinic (0.1 FTE) and week for specialisation	Number of REVIEW encounters seen per clinic (0.1 FTE) and week for specialisation	Number of inpatients seen per 0.1 FTE for specialisation	Average total FTE (public+private) for each specialisation
	n (percentage)	mean (SD; range)			
Epilepsy					
	138 (23.9%)	1.84 (1.89; 0-12)	4.28 (5.71; 0-45)	1.12 (1.85; 0-12)	0.32 (0.27; 0-1)
MS/neuroimmunology					
	133 (23.1%)	1.16 (1.19; 0-6)	3.46 (3.67; 0-20)	0.42 (1.31; 0-12)	0.21 (0.17; 0-1)
Neuromuscular					
	101 (17.5%)	1.55 (1.86; 0-10)	2.99 (3.94; 0-24)	0.20 (0.68; 0-5)	0.17 (0.15; 0.1-0.9)
Movement disorders					
	108 (18.7%)	1.66 (1.83; 0-10)	4.11 (6.35; 0-50)	0.57 (1.64; 0-10)	0.27 (0.23; 0-1)

Stroke					
	153 (26.5%)	1.50 (2.93; 0-30)	1.86 (2.82; 0-20)	3.81 (6.02; 0-36)	0.33 (0.28; 0-1)
Clinical neurophysiology					
	154 (26.7%)	5.01 (5.14; 0-32)	0.33 (1.22; 0-10)	0.53 (1.42; 0-10)	0.24 (0.22; 0-1)
Cognitive/behavioural neurology					
	43 (7.5%)	1.02 (1.18; 0-5)	2.09 (3.56; 0-20)	0.77 (2.07; 0-12)	0.17 (0.08; 0.1-0.3)
Headache					
	94 (16.3%)	1.54 (1.56; 0-6)	3.35 (5.46; 0-45)	0.49 (1.20; 0-6)	0.21 (0.22; 0-1)
Neuro-ophthalmology					
	32 (5.6%)	0.91 (1.28; 0-5)	1.66 (2.18; 0-7)	0.16 (0.37; 0-1)	0.15 (0.14; 0-0.5)
Neuro-otology					
	29 (5.0%)	2.03 (2.85; 0-12)	3.17 (5.99; 0-30)	0.28 (0.53; 0-2)	
General neurology					
	387 (67.1%)	2.65 (3.83; 0-40)	4.94 (6.95; 0-60)	2.82 (4.61; 0-30)	0.42 (0.31; 0-1)

Other					
	17 (3.0%)	1.94 (3.29; 0-12)	2.82 (5.78; 0-22)	0.35 (1.22; 0-5)	0.2 (0.13; 0.1-0.5)

Supplemental Table 7. Estimation of supply and demand of neurological care in Australia in 2020 and 2034 including interventions.

	2020	2034	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031	+20 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	620	896	935	973	1051
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56

Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial Pts/year[b]	441,489.60	638,023.68	665,794.80	692,853.84	748,396.08
Review Pts/year[c]	878,180.40	1,269,112.32	1,324,352.70	1,378,176.66	1,488,657.42
Demand for neurological care[d]					
Initial encounters/year	172,099.08	219,041.47	219,041.47	219,041.47	219,041.47
Review encounters/year	2,200,696.20	2,766,987.22	2,766,987.22	2,766,987.22	2,766,987.22

Difference between supply and demand of neurological care[d]					
Initial encounters/year	Demand fully met	Demand fully met	Demand fully met	Demand fully met	Demand fully met
Review encounters/year	-1,322,515.80	-1,497,874.90	-1,442,634.52	-1,388,810.56	-1,278,329.80
Supply vs Demand based on Australia national disease-specific patient counts[d], 10%					

Initial allocation first, then remaining capacity to Review					
Initial encounters/year	-154,889.17	-197,137.32	-197,137.32	-197,137.32	-197,137.32
Review encounters/year	-898,236.11	-881,755.37	-798,743.87	-717,860.87	-551,837.87

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 8. Estimation of durational supply and demand for neurological care in Australia, 2020 to 2034 with intervention scenarios.

	2020	2034	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031	+20 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	620	896	935	973	1051
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial encounters/year[b]	441,489.60	638,023.68	665,794.80	692,853.84	748,396.08

Review encounters/year[c]	878,180.40	1,269,112.32	1,324,352.70	1,378,176.66	1,488,657.42
Patient Durational Supply, Hours (60 min per new, 30 min per review)					
Initial encounters/year[b]	344,361.89	497,658.47	519,319.94	540,426.00	583,748.94
Review encounters/year[c]	342,490.36	494,953.80	516,497.55	537,488.90	580,576.39

Durational demand for neurological care[d]					
Initial encounters/year	134,447.29	171,878.64	171,878.64	171,878.64	171,878.64
Review encounters/year	880,875.74	1,087,167.43	1,087,167.43	1,087,167.43	1,087,167.43
Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d].					

Initial encounters/year	Demand fully met	Demand fully met	Demand fully met	Demand fully met	Demand fully met
Review encounters/year	-538,385.39	-592,213.62	-570,669.87	-549,678.53	-506,591.03
Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d], 10% Initial allocation first, then remaining					

capacity to Review					
Initial encounters/year	-121,002.56	-154,007.67	-154,007.67	-154,007.67	-154,007.67
Review encounters/year	-207,468.23	-111,667.12	-68,461.89	-26,364.50	Demand fully met

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 9. Neurology patient supply and demand estimation, regional Australia, 2020 to 2034, updated prevalence and incidence-based demand estimates with intervention scenarios.

	2020	2034	+2 neurologists per year, 2022-2031	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	25	33	46	65	97
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94

Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	35,410.50	46,741.86	65,155.32	92,067.30	137,392.74
Demand for neurological care[d]					
Initial encounters/year	53,350.71	67,902.86	67,902.86	67,902.86	67,902.86
Review encounters/year	682,215.82	857,766.04	857,766.04	857,766.04	857,766.04
Supply vs Demand based on Australia national disease-					

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specific patient counts[d].					
Initial encounters/year	-35,548.71	-44,404.22	-35,147.18	-21,617.66	Demand fully met
Review encounters/year	-646,805.32	-811,024.18	-792,610.72	-765,698.74	-720,373.30
Supply vs Demand based on Australia national disease-specific patient counts[d], 10% Initial allocation first, then remaining capacity to Review					

Initial encounters/year	-48,015.64	-61,112.57	-61,112.57	-61,112.57	-61,112.57
Review encounters/year	-634,356.88	-794,315.82	-766,645.32	-726,203.82	-658,091.82

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 10. Estimation of durational supply and demand for neurological care in regional Australia, 2020 to 2034, with intervention scenarios.

	2020	2034	+2 neurologists per year, 2022-2031	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031

Supply of neurological care					
Neurologists	25	33	46	65	97
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	35,410.50	46,741.86	65,155.32	92,067.30	137,392.74

Patient Durational Supply, Hours (60 min per new, 30 min per review)					
Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	17,705.25	23,370.93	32,577.66	46,033.65	68,696.37
Durational demand for neurological care[d]					
Initial encounters/year	13,885.56	18,328.94	25,549.43	36,102.46	53,875.97
Review encounters/year	13,810.10	18,229.33	25,410.57	35,906.25	53,583.17

Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d].					
Initial encounters/year	-27,793.10	-34,718.15	-27,497.66	-16,944.63	Demand fully met
Review encounters/year	-259,261.39	-318,792.58	-311,611.33	-301,115.66	-283,438.73
Supply vs 1-year average Durational Demand based on Australia national					

disease-specific patient counts[d], 10% Initial allocation first, then remaining capacity to Review					
Initial encounters/year	-37,510.79	-47,742.38	-47,742.38	-47,742.38	-47,742.38
Review encounters/year	-249,543.69	-305,768.35	-291,366.61	-270,317.91	-234,867.47

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 11. Estimation of patient supply/demand for Australia, 2020, assessing different fractions of Initial encounter demand allocation.

		Allocation of Initial demand of neurology care before remaining capacity preferentially allocated to Review demand of neurology care				
	Simple difference	10%	20%	30%	40%	50%
Supply vs demand						
Initial met	172,099.08	17,209.91	34,419.82	51,629.72	68,839.63	86,049.54
Initial not met	0.00	154,889.17	137,679.26	120,469.35	103,259.45	86,049.54
Review met	878,180.4	1,302,400.46	1,285,130.92	1,267,861.37	1,250,591.83	1,233,322.29
Review not met	-1,322,515.80	-898,295.74	-915,565.28	-932,834.83	-950,104.37	-967,373.91
Durational supply vs demand						
Initial met	134,447.29	13,444.73	26,889.46	40,334.19	53,778.92	67,223.64
Initial not met	0.00	121,002.56	107,557.83	94,113.10	80,668.37	67,223.64

Review met	342,490.36	673,407.52	659,962.79	646,518.06	633,073.33	619,628.60
Review not met	-538,385.39	-207,468.23	-220,912.96	-234,357.69	-247,802.41	-261,247.14

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Appendices

Supplemental Table 1. Estimated new and review patient load, Australia, 2020.

	Initial patients					Review patients					
	Prop. Likely to see neurologist	Initial encounter duration, min.	Incidence rate per 100,000 person-years	Initial case load	Initial case durational load, hours	Prop. likely to see neurologist	Review encounter frequency	Review encounter duration, min.	Prevalence per 100,000 persons	Review case load	Review case duration load, hours
Autoimmune encephalitis	30%	60	0.80[1]	61.69	61.69	30%	3	30	13.70[1]	3,169.38	554.64
Nervous system cancers	60%	60	7.20[2]	1,110.44	1,110.44						
Traumatic brain injury	5%	60	939.00[3]	12,068.31	12,068.31	5%	1	30	12111.08[4]	155,655.31	77,827.66

CIDP and chronic neuropathies	100%	40	0.33[5]	84.83	56.55	100%	2	20	2.81[5]	1,444.60	481.53
Encephalitis, infectious	5%	60	5.00[2]	64.26	64.26	0%					
Epilepsy	100%	40	61.44[6]	15,792.91	10,528.61	50%	2	20	638.00[6]	163,995.37	54,665.12
Functional neurological disorders	100%	60	29.50[7]	7,582.86	7,582.86	20%	2	30	37.20[7]	3,824.84	286.86
Guillain-Barre	100%	40	1.11[8]	285.32	190.21	50%	2	20	1.90[9]	488.39	24.42
Migraine	15%	40	810.00[10]	31,231.09	20,820.73	15%	2	20	15000.00[11]	1,156,707.1	385,569.05
Motor neurone disease	100%	40	0.78[12]	200.50	133.66	100%	3	30	4.50[12]	3,470.12	1,735.06

Multiple sclerosis and neuroimmunology	100%	60	3.30[2]	848.25	848.25	100%	2	30	103.70[13]	53,311.35	26,655.67
Myasthenia gravis	100%	60	0.53[14]	136.23	136.23	100%	2	30	7.77[14]	3,994.50	1,997.25
Myopathies, inflammatory	50%	60	0.80[15]	102.56	102.56	0%					
Neurocognitive disorders	20%	60	923.06[16] (60+yo)	10,615.09	10,615.09	10%	1	30	13402.35[17] (65+yo)	57,577.14	28,788.57
Optic neuritis	50%	60	3.70[18]	475.54	475.54	0%					
Pain (neuropathic, vertebrogenic)	5%	40	820.00[19]	10,538.89	7,025.92	5%	2	20	9,800.00[20]	2,519,051.09	83,968.37

Parkinson's disease & Movement disorders	90%	60	13.43 [21]	3,106.92	3,106.92	90%	2	60	106.28 [21]	124,574.40	124,574.40
Peripheral nerve injuries	50%	60	13.90 [22]	1,786.47	1,786.47	0%					
Peripheral neuropathy/ neuritis	10%	60	790.00 [23]	20,306.64	20,306.64	10%	2	30	2360.00 [23 24]	121,325.73	60,662.86
Sleep disorders						5%	1	20	6947.17 [25]	89,287.18	29,762.39
Obstructive sleep apnoea	5%	40	139.20 [26]	1,789.04	1,192.69						
Insomnia	5%	40	1842.95 [27] (35+yo)	12,933.84	8,622.56						

Spinal cord injury	5%	60	1.45[28]	372.72	18.64	0%					
Stroke	95%	40	159.00 [29]	38,762.54	36,824.41	5%	1	20	1316.30 [29]	2,043.50	681.17
Transverse myelitis	95%	60	3.10[30]	796.84	757.00	0%					
Trigeminal neuralgia	50%	40	9.90[31]	2,544.76	1,272.38	50%	4	20	9.90[32]	7,922.16	2,640.72
Total				172,099.08	134,447.29					2,200,696.20	880,875.74
Abbreviations: CIDP= Chronic inflammatory demyelinating											

polyradiculoneuro pathy.											

Supplemental Table 2. Estimated new and review patient load, Australia, 2034. This estimate is based on the current epidemiological data, projected for the forecasted population growth.

	Initial patients					Review patients					
	Prop. likely see neurologist	Consult duration, min.	Incidence rate	Initial case load	Initial case durational load, hours	Prop. likely see neurologist	Consult frequency	Consult duration, min.	Prevalence	Review case load	Review case duration load, hours
Autoimmune encephalitis	30%	60	0.80[1]	78.52	78.52	30%	3	30	13.70[1]	4,033.87	705.93
Nervous system cancers	60%	60	7.20[2]	1,413.33	1,413.33						0.00
Traumatic brain injury	5%	60	939.00[3]	15,360.11	15,360.11	5%	1	30	12111.08[4]	198,112.46	99,056.23

CIDP and chronic neuropathies	100%	40	0.33[5]	107.96	71.97	100%	2	20	2.81[5]	1,838.63	612.88
Encephalitis, infectious	5%	60	5.00[2]	81.79	81.79	0%					
Epilepsy	100%	40	61.44[6]	20,100.64	13,400.43	50%	2	20	638.00[6]	208,727.38	69,575.79
Functional neurological disorders	100%	60	29.50[7]	9,651.19	9,651.19	20%	2	30	37.20[7]	4,868.12	365.11
Guillain-Barre	100%	40	1.11[8]	363.15	242.10	50%	2	20	1.90[9]	621.60	31.08
Migraine	15%	40	810.00[10]	39,749.81	26,499.87	15%	2	20	15000.00[11]	1,472,215.05	490,738.35
Motor neurone disease	100%	40	0.78[12]	255.18	170.12	100%	3	30	4.50[12]	4,416.65	2,208.32

Multiple sclerosis and neuroimmunol.	100%	60	3.30[2]	1,079.62	1,079.62	100%	2	30	103.70[13]	67,852.76	33,926.38
Myaesthenia gravis	100%	60	0.53[14]	173.39	173.39	100%	2	30	7.77[14]	5,084.05	2,542.02
Myopathies, inflammatory	50%	60	0.80[15]	130.54	130.54	0%					
Neurocognitive disorders	20%	60	923.06[16] (60+yo)	13,510.48	13,510.48	10%	1	30	13402.35[17] (65+yo)	73,282.11	36,641.05
Optic neuritis	50%	60	3.70[18]	605.24	605.24	0%					
Pain (neuropathic, vertebrogenic)	5%	40	820.00[19]	13,413.51	8,942.34	5%	2	20	9,800.00[20]	320,615.72	106,871.91

Parkinson's & Movement disorders	90%	60	13.43[21]	3,954.37	3,954.37	90%	2	60	106.28[21]	124,574.40	124,574.40
Peripheral nerve injuries	50%	60	13.90[22]	2,273.75	2,273.75	0%					
Peripheral neuropathy/ neuritis	10%	60	790.00[23]	25,845.55	25,845.55	10%	2	30	2360.00[23] [24]	154,419.00	77,209.50
Sleep disorders						5%	1	20	6947.17[25]	113,641.49	37,880.50
Obstructive sleep apnoea	5%	40	139.20[26]	2,277.03	1,518.02						
Insomnia	5%	40	1842.95 [27] (35+yo)	16,461.72	10,974.48						

Spinal cord injury	5%	60	1.45[28]	23.72	23.72	0%					
Stroke	95%	40	159.00[29]	49,417.07	32,944.71	5%	1	20	1316.30[29]	2,600.90	866.97
Transverse myelitis	95%	60	3.10[30]	963.48	963.48	0%					
Trigeminal neuralgia	50%	40	9.90[31]	1,619.44	1,079.62	50%	4	20	9.90[32]	10,083.04	3,361.01
Total				219,041.47	171,119.63					2,766,987.22	1,087,167.43
Abbreviations: CIDP= Chronic inflammatory demyelinating polyradiculoneuropathy.											

Supplemental Table 3. Estimating number of Active Neurology Consultant Fellows of the RACP, practicing in Adult Neurology in Australia from RACP Internal Membership Reports.

	2020[33]	2019[34]
RACP Members	27,843	26,761
In Australia	23,303 (83.7%)	22,330 (83.4%)
RACP Fellows	18,863 (67.8%)	18,071 (67.5%)
Active RACP Fellows	17,160 (61.6%) (91.0% of Fellows)	16,435 (61.4%) (91.0% of Fellows)
Australian RACP Fellows	15,641 (82.9%)	14,919 (66.8%)
Australian Active RACP Fellows	14,436 (51.8%)	13,774 (51.5%)
Australian Active RACP Fellows	14,436	13,774
Major Urban	12,685 (87.9%)	12,133 (88.1%)
Inner Regional	1,235 (8.6%)	1,150 (8.3%)
Outer Regional	445 (3.1%)	424 (3.1%)

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Remote	70 (0.5%)	65 (0.5%)
Neurology	960	901
Adult Neurology practitioners (including non-fellows)	852 (88.8%)	800 (88.8%)
Neurology Fellows	756 (78.8%)	710 (78.8%)
Neurology RACP Fellows x % in Australia x % Active x % Adult Neurology	756x83.7%x91.0%x88.8%	710x83.4%x91.0x88.8%
Number of Active, Neurology RACP Fellows working in Australia who work in Adult Neurology (does not include neurology trainees)	**511**	**479**

Supplemental Table 4. Allocation of model parameters based on data from MBA, RACP, Medical Deans ANZ Student Statistics, and ANZAN survey.

	μ	α	M(0)	λ_m	T(0)	λ_t	E(0)	λ_e	L(0)	s_1	S(0)	$s_2+\gamma$	Total neurologists
2020	0.38	3,637	4,155	0.44	106	47	208	35	299	3.5 (0.9% PY)	4	0.46	617
2019	0.53	3,693	3,996	0	96	47	195		280		4	0.40	575
2018	0.48	3,475	4,052	2	90	45	193		277		3		564
2017		3,569	3,569		83	22	187		267		3		540
2016		3,547				1							422
2015		3,437				25							421

Number of Advanced Physician Trainees in neurology (T); Number of Early-Career neurology consultants (E): from the 2020 ANZAN survey; Number of Mid/Late-Career neurology consultants (L): from the 2020 ANZAN survey; Number of semi-retired (S): From the 2020 ANZAN survey; Immigration (μ): μ is derived from data from the Medical Board of Australia international medical graduate applications; Rate of Basic Physician Trainees admitted into Advanced Neurology Trainees (λ_m): from ANZAN records; Rate of Retirement: from RACP annual reports; Rates of transition from Advanced Neurology Trainee to Early-Career Neurologist (λ_t) and from Early-Career Neurologist to Mid/Late-Career Neurologist (λ_e) are dynamically estimated within the function by the Total Neurology Consultant numbers and the values of the other model components; Rate of conversion from semi-retired to retired (s2) and rate of conversion to retired, emigrated, and left neurology (γ).

Supplemental Table 5. ANZAN survey respondent characteristics.

	n (%)	
	Total survey sample (n=738)	Australian, Active, Working in last 12 months, Works with adults (n=577)
Sex		
Male	472 (64.0%)	370 (64.1%)
Female	265 (35.9%)	206 (35.7%)
Unspecified	1 (0.1%)	1 (0.2%)

ANZAN member		
No	6 (0.8%)	5 (0.9%)
Yes	732 (99.2%)	572 (99.1%)
Working status		
Active	714 (96.8%)	577 (100%)
TNIP	9 (1.2%)	
Semi-retired	13 (1.8%)	
Retired	2 (0.3%)	
Country of secondary school		
Australia	236 (68.2%)	214 (72.8%)
New Zealand	30 (8.7%)	9 (3.1%)
Other	80 (23.1%)	71 (24.2%)
(Missing)	(392 (53.1%))	(283 (49.1%))
Country of medical school		

Australia	378 (70.9%)	332 (76.2%)
New Zealand	42 (7.9%)	8 (1.8%)
Other	113 (21.2%)	96 (22.0%)
(Missing)	(205 (27.8%))	(141 (24.4%))
Country of specialist training		
Australia	362 (81.0%)	325 (87.8%)
New Zealand	25 (5.6%)	3 (0.8%)
Other	60 (13.4%)	42 (11.4%)
(Missing)	(291 (39.4%))	(207 (35.9%))
Country of current work		
Australia	649 (879%)	577 (100%)
New Zealand	58 (7.9%)	
Other	31 (4.2%)	

Adult/paediatric neurology		
Neither	29 (3.9%)	14 (2.4%)
Adult only	692 (93.8%)	558 (96.7%)
Paediatric only	11 (1.5%)	0 (0%)
Both	6 (0.8%)	5 (0.9%)
Advanced physician trainee?		
No	565 (76.6%)	447 (77.5%)
Yes	173 (23.4%)	130 (22.5%)
	Mean (SD; range)	
Age (missing 2)	44.68 (12.43; 20-85)	44.26 (11.96; 26-84)
Abbreviations: ANZAN = Australia New Zealand Association of Neurologists; TNIP = Temporarily not in practice.		

Supplemental Table 6. Neurology specialisations and mean patient numbers/FTE fractions from 2020 ANZAN survey, restricted to 577 respondents who were active, adult neurologists, working in Australia.

	Number of practitioners who work in a neurological specialty (out of 577)?	Number of NEW encounters per clinic (0.1 FTE) and week for specialisation	Number of REVIEW encounters seen per clinic (0.1 FTE) and week for specialisation	Number of inpatients seen per 0.1 FTE for specialisation	Average total FTE (public+private) for each specialisation
	n (percentage)	mean (SD; range)			
Epilepsy					
	138 (23.9%)	1.84 (1.89; 0-12)	4.28 (5.71; 0-45)	1.12 (1.85; 0-12)	0.32 (0.27; 0-1)
MS/neuroimmunology					
	133 (23.1%)	1.16 (1.19; 0-6)	3.46 (3.67; 0-20)	0.42 (1.31; 0-12)	0.21 (0.17; 0-1)
Neuromuscular					
	101 (17.5%)	1.55 (1.86; 0-10)	2.99 (3.94; 0-24)	0.20 (0.68; 0-5)	0.17 (0.15; 0.1-0.9)
Movement disorders					
	108 (18.7%)	1.66 (1.83; 0-10)	4.11 (6.35; 0-50)	0.57 (1.64; 0-10)	0.27 (0.23; 0-1)

Stroke					
	153 (26.5%)	1.50 (2.93; 0-30)	1.86 (2.82; 0-20)	3.81 (6.02; 0-36)	0.33 (0.28; 0-1)
Clinical neurophysiology					
	154 (26.7%)	5.01 (5.14; 0-32)	0.33 (1.22; 0-10)	0.53 (1.42; 0-10)	0.24 (0.22; 0-1)
Cognitive/behavioural neurology					
	43 (7.5%)	1.02 (1.18; 0-5)	2.09 (3.56; 0-20)	0.77 (2.07; 0-12)	0.17 (0.08; 0.1-0.3)
Headache					
	94 (16.3%)	1.54 (1.56; 0-6)	3.35 (5.46; 0-45)	0.49 (1.20; 0-6)	0.21 (0.22; 0-1)
Neuro-ophthalmology					
	32 (5.6%)	0.91 (1.28; 0-5)	1.66 (2.18; 0-7)	0.16 (0.37; 0-1)	0.15 (0.14; 0-0.5)
Neuro-otology					
	29 (5.0%)	2.03 (2.85; 0-12)	3.17 (5.99; 0-30)	0.28 (0.53; 0-2)	
General neurology					
	387 (67.1%)	2.65 (3.83; 0-40)	4.94 (6.95; 0-60)	2.82 (4.61; 0-30)	0.42 (0.31; 0-1)

Other					
	17 (3.0%)	1.94 (3.29; 0-12)	2.82 (5.78; 0-22)	0.35 (1.22; 0-5)	0.2 (0.13; 0.1-0.5)

Supplemental Table 7. Estimation of supply and demand of neurological care in Australia in 2020 and 2034 including interventions.

	2020	2034	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031	+20 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	620	896	935	973	1051
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56

Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial Pts/year[b]	441,489.60	638,023.68	665,794.80	692,853.84	748,396.08
Review Pts/year[c]	878,180.40	1,269,112.32	1,324,352.70	1,378,176.66	1,488,657.42
Demand for neurological care[d]					
Initial encounters/year	172,099.08	219,041.47	219,041.47	219,041.47	219,041.47
Review encounters/year	2,200,696.20	2,766,987.22	2,766,987.22	2,766,987.22	2,766,987.22

Difference between supply and demand of neurological care[d]					
Initial encounters/year	Demand fully met	Demand fully met	Demand fully met	Demand fully met	Demand fully met
Review encounters/year	-1,322,515.80	-1,497,874.90	-1,442,634.52	-1,388,810.56	-1,278,329.80
Supply vs Demand based on Australia national disease-specific patient counts[d], 10%					

Initial allocation first, then remaining capacity to Review					
Initial encounters/year	-154,889.17	-197,137.32	-197,137.32	-197,137.32	-197,137.32
Review encounters/year	-898,236.11	-881,755.37	-798,743.87	-717,860.87	-551,837.87

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 8. Estimation of durational supply and demand for neurological care in Australia, 2020 to 2034 with intervention scenarios.

	2020	2034	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031	+20 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	620	896	935	973	1051
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial encounters/year[b]	441,489.60	638,023.68	665,794.80	692,853.84	748,396.08

Review encounters/year[c]	878,180.40	1,269,112.32	1,324,352.70	1,378,176.66	1,488,657.42
Patient Durational Supply, Hours (60 min per new, 30 min per review)					
Initial encounters/year[b]	344,361.89	497,658.47	519,319.94	540,426.00	583,748.94
Review encounters/year[c]	342,490.36	494,953.80	516,497.55	537,488.90	580,576.39

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Durational demand for neurological care[d]					
Initial encounters/year	134,447.29	171,878.64	171,878.64	171,878.64	171,878.64
Review encounters/year	880,875.74	1,087,167.43	1,087,167.43	1,087,167.43	1,087,167.43
Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d].					

Initial encounters/year	Demand fully met	Demand fully met	Demand fully met	Demand fully met	Demand fully met
Review encounters/year	-538,385.39	-592,213.62	-570,669.87	-549,678.53	-506,591.03
Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d], 10% Initial allocation first, then remaining					

capacity to Review					
Initial encounters/year	-121,002.56	-154,007.67	-154,007.67	-154,007.67	-154,007.67
Review encounters/year	-207,468.23	-111,667.12	-68,461.89	-26,364.50	Demand fully met

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

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Supplemental Table 9. Neurology patient supply and demand estimation, regional Australia, 2020 to 2034, updated prevalence and incidence-based demand estimates with intervention scenarios.

	2020	2034	+2 neurologists per year, 2022-2031	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031
Supply of neurological care					
Neurologists	25	33	46	65	97
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94

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Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	35,410.50	46,741.86	65,155.32	92,067.30	137,392.74
Demand for neurological care[d]					
Initial encounters/year	53,350.71	67,902.86	67,902.86	67,902.86	67,902.86
Review encounters/year	682,215.82	857,766.04	857,766.04	857,766.04	857,766.04
Supply vs Demand based on Australia national disease-					

specific patient counts[d].					
Initial encounters/year	-35,548.71	-44,404.22	-35,147.18	-21,617.66	Demand fully met
Review encounters/year	-646,805.32	-811,024.18	-792,610.72	-765,698.74	-720,373.30
Supply vs Demand based on Australia national disease-specific patient counts[d], 10% Initial allocation first, then remaining capacity to Review					

Initial encounters/year	-48,015.64	-61,112.57	-61,112.57	-61,112.57	-61,112.57
Review encounters/year	-634,356.88	-794,315.82	-766,645.32	-726,203.82	-658,091.82

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 10. Estimation of durational supply and demand for neurological care in regional Australia, 2020 to 2034, with intervention scenarios.

	2020	2034	+2 neurologists per year, 2022-2031	+5 neurologists per year, 2022-2031	+10 neurologists per year, 2022-2031

Supply of neurological care					
Neurologists	25	33	46	65	97
Weeks/year	43	43	43	43	43
Initial Pts per week (2.75 per clinic)[a]	16.56	16.56	16.56	16.56	16.56
Review Pts per week (5.49 per clinic)[a]	32.94	32.94	32.94	32.94	32.94
Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	35,410.50	46,741.86	65,155.32	92,067.30	137,392.74

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Patient Durational Supply, Hours (60 min per new, 30 min per review)					
Initial encounters/year[b]	17,802.00	23,498.64	32,755.68	46,285.20	69,071.76
Review encounters/year[c]	17,705.25	23,370.93	32,577.66	46,033.65	68,696.37
Durational demand for neurological care[d]					
Initial encounters/year	13,885.56	18,328.94	25,549.43	36,102.46	53,875.97
Review encounters/year	13,810.10	18,229.33	25,410.57	35,906.25	53,583.17

Supply vs 1-year average Durational Demand based on Australia national disease-specific patient counts[d].					
Initial encounters/year	-27,793.10	-34,718.15	-27,497.66	-16,944.63	Demand fully met
Review encounters/year	-259,261.39	-318,792.58	-311,611.33	-301,115.66	-283,438.73
Supply vs 1-year average Durational Demand based on Australia national					

disease-specific patient counts[d], 10% Initial allocation first, then remaining capacity to Review					
Initial encounters/year	-37,510.79	-47,742.38	-47,742.38	-47,742.38	-47,742.38
Review encounters/year	-249,543.69	-305,768.35	-291,366.61	-270,317.91	-234,867.47

a. Initial and review patient numbers derived from 2020 ANZAN Member Survey.

b. Patient capacity for Initial encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Initial Patients per week.

c. Patient capacity for Review encounters estimated as: Number of neurologists *x* FTE fraction *x* Weeks/year *x* # Review Patients per week.

d. Estimated new and review patient load based on disease-specific patient counts as in Supplemental Table 1.

Supplemental Table 11. Estimation of patient supply/demand for Australia, 2020, assessing different fractions of Initial encounter demand allocation.

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		Allocation of Initial demand of neurology care before remaining capacity preferentially allocated to Review demand of neurology care				
	Simple difference	10%	20%	30%	40%	50%
Supply vs demand						
Initial met	172,099.08	17,209.91	34,419.82	51,629.72	68,839.63	86,049.54
Initial not met	0.00	154,889.17	137,679.26	120,469.35	103,259.45	86,049.54
Review met	878,180.4	1,302,400.46	1,285,130.92	1,267,861.37	1,250,591.83	1,233,322.29
Review not met	-1,322,515.80	-898,295.74	-915,565.28	-932,834.83	-950,104.37	-967,373.91
Durational supply vs demand						
Initial met	134,447.29	13,444.73	26,889.46	40,334.19	53,778.92	67,223.64
Initial not met	0.00	121,002.56	107,557.83	94,113.10	80,668.37	67,223.64

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Review met	342,490.36	673,407.52	659,962.79	646,518.06	633,073.33	619,628.60
Review not met	-538,385.39	-207,468.23	-220,912.96	-234,357.69	-247,802.41	-261,247.14

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