Forecasting future medical specialty workforces supply with age distribution using health workforce annual practicing certificate data

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Abstract

Objectives: To introduce a newly developed workforce forecasting model (the model) using historic annual practicing certificate (APC) data to forecast future supply of medical specialty workforce with age distribution for each specialty.

Methods: We tracked individual medical specialist APC data for the last 6 to 10 years to gather age or age-group, specialty specific exit rates, full time equivalent (FTE) per head count (HC) ratios, and entry/re-entry age distributions. These parameters were used with an in-house developed dynamic modelling algorithm to forecast future medical specialty workforce supply in New Zealand. The input parameters and the model has been gradually improved and validated through numerous discussions with medical colleges, and associations.

Results: The model calculated the age distribution of each specialty workforces over the next 10 years, and projected that many specialty workforces may have a lower ratio of specialists to corresponding population groups in 2026 compared to 2016

Conclusions: The model has opened a new way of using APC data for evidence-informed planning and policy development, and the outputs of the model have been used within the New Zealand health sector. The model is easily scalable and can be adapted for other workforces and used in regional workforce planning.

Key words
health workforce, workforce forecasting, workforce planning, dynamic modelling, annual practicing certificate

Introduction

Medical workforces in OECD countries such as Australia, the United Kingdom, Canada and the United States of America have shifted from predictions of surplus to warnings of shortages [1]. The standardised approach of the National Health Workforce Taskforce (NHWT) in Australia did not adequately account for the specific circumstances of the Northern territory (NT) and the NHWT modelled health workforce and to incorporate variables of specific importance to the NT [2]. Better data would enhance the quality of the supply projections [2]. Shortages of pathologists in the United States of America [3], neurological services in New Zealand [4] and an equal or lower ratio of plastic surgeons to the population in comparable countries [5] would need to be resolved to meet the demand.

Health Workforce New Zealand [6] (HWNZ) is a unit within the New Zealand Ministry of Health [7] (MoH), New Zealand. HWNZ provides national leadership as it works with stakeholders involved in the development of the health workforce to enhance strategic planning and decision making. The spending for medical vocational training is the highest proportion of HWNZ's training budget so identifying medical specialty workforce requirement is quite critical for the delivery of health services and government's health initiatives, such as The National Bowel Cancer Programme [8].

The development of the workforce forecasting model (the model) provides insight to a possible solution to the problem unique to a given situation by simulating a variety of options with respect to changing policies and plans. The model utilised in this investigation fulfilled the supply forecast model of medical specialty workforce similar to the FutureDocs Forcasting tool, which was developed by the University of North Carolina Chapel Hill [9]. The model assists HWNZ in workforce prioritisation, the planning of training volumes in collaboration with medical colleges, understanding future workforce age distributions, and estimating future medical specialty workforce capacity.

Method

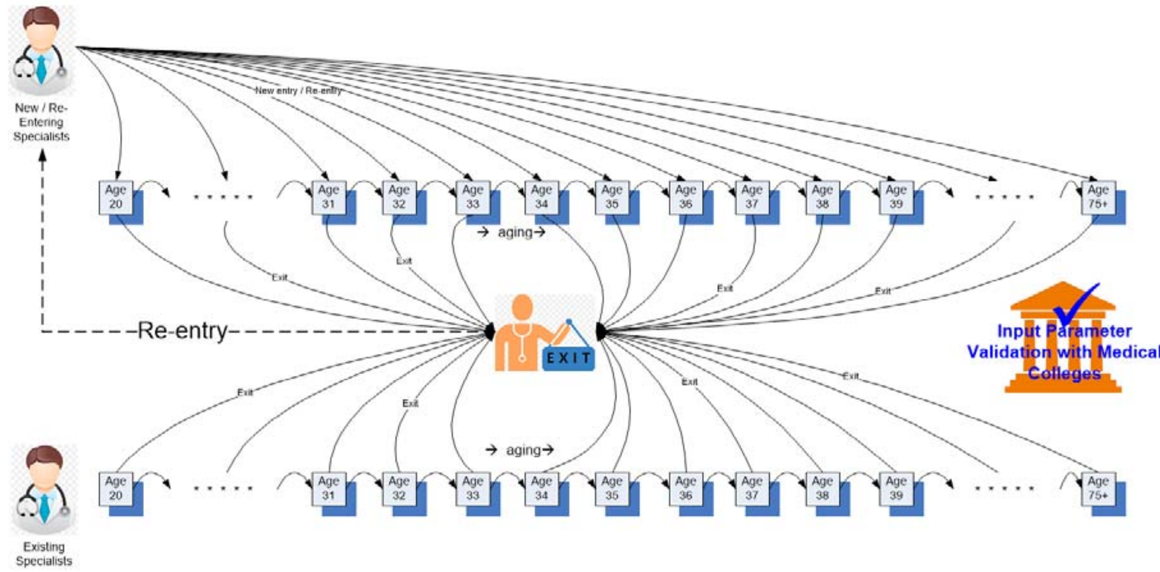
Main structure of the model

The forecasting model consists of two parts. For the first part, we tracked every single doctor who had annual practicing certificate (APC) in New Zealand in 2006 to 2016. The APC data was sourced from the Medical Council of New Zealand's 2006 to 2016 registration database and 2014 Workforce Survey (which was the latest data available as at March 2017). By tracking every single doctor, we were able to calculate workforce parameters, such as entry/re-entry age-group distribution, age-group specialty exit rates, age-group and specialty specific full time equivalent (FTE) per head count (HC) ratios. We have SAS® (SAS Institute Inc., Cary, NC, USA) for most of parameter calculations.

The second part of the model used an aging algorithm based on the parameters calculated in the first part.

The model allows various workforce movements, including the aging of a workforce, exiting, and entering/returning. These workforce movements can be updated every year for each specialty workforce. The main concept of the algorithm is illustrated in figure 1.

Figure1 – Concept of the model



We have split the workforce into two different streams to identify how many specialists are going to be replaced by new or returning specialists in the next 10 years. One of the streams is the existing workforce who are practicing in the base year. We let them age in the model, and exit based on the exit rates specific to their age group and specialty. Another stream is the new/returning workforce. They also age within the model and exit based on the exit rates specific to their age group and specialty.

The model is designed to virtually and automatically update the forecasted number of the workforce volume. The forecasting incorporates ageing, and workforce inflow/outflow to project the size of the workforce in both HC and FTE.

The functionality of the models in this article has been progressively improved over 20 months to consider a variety of variables that are important to the New Zealand health context.

Exit rates

The model uses variable exit rates for every future year independently. For every future year, the exit rates are applied to the current workforce, and updates the workforce volumes for the year.

The exit rates of a workforce includes mortality, change of professions, having a long term break, and immigration.

The exit rates has been calculated by analysing individual specialists' APC renewal patterns observed for 2006 to 2015 for some specialties, but most specialties are based on 2010 to 2015. The period selection has been finalised from the discussion with corresponding medical colleges.

For the entering/returning workforces who just joined in the current year, the model uses half of the yearly exit rate to allow different joining times of the year.

The model uses age, and specialty specific exit rates. The different rates reflect the different characteristics in each specialty.

Entry/Re-Entry volumes and its age distributions

The model uses combined entry volume for new entrants and re-entrants to the workforce. The volume can be variable in the future years, and variable entry age distributions is also used for every future year.

The entry number for each specialty is identified by analysing individual specialists' Annual Practicing Certificate (APC) renewals patterns observed from 2010 to 2015, and future plan of training volume supplied from the corresponding medical colleges to make the entry variable.

The combined entrants includes doctors who have finished their registrar training, immigrated to New Zealand, and returned to the workforce after having a break.

We decided to combine new entry and re-entry data as the model is unable to distinguish temporary from permanent exit numbers. However it can distinguish between matching re-entry and new entry numbers.

The combined entry and re-entry numbers may appear to result in an inflated number of entries to some readers, but re-entry and temporary exit numbers cancel each other in the model; therefore, the accuracy of the forecasting workforce is un-affected.

FTE per HC Ratios

The model also uses age and specialty specific FTE per HC ratios, which are applied to every future year independently.

The Medical Council of New Zealand also collects average weekly working hours for each doctor as a part of their workforce surveys, which are collected when APCs are renewed. Using the average weekly working hours in each specialty, we calculated the FTE per head count ratios for each age and specialty. In this model, the FTE per HC ratio is sourced from the 2014 Medical Council of New Zealand Workforce Survey, unless corresponding college has other data that they believe to be more suitable for the future years.

The FTE per HC ratio is not only used for predicting FTE volumes, but also identifying generational, or feminisation characteristics of any specialty workforce. Therefore the model accounts for doctors who may have reduced hours when they are of child-bearing age, and a tendency for doctors in younger age to reduce their hours.

Basic definitions for formulas used in the model

Let $i = \text{age } 20,21,22, \ldots, 75+$
Let $j = \text{Anaesthesia, Cardiothoracic Surgery, Clinical Genetics, } \ldots\ldots, \text{Vascular surgery}$
Let $k = 0(\text{base year}), 1,2,3,4,5,6,7,8,9,10$
Let $O_{i,j,k}$ = Number of pre-existing specialists for i age, j specialty, after k year(s)
Let $E_{i,j,k}$ = Number of entered specialists remain after k year(s)
Let 1 Full Time Equivalent (FTE) = 40 Hours per week
Let $R_{i,j,k}$ = Ratio of FTE per Head Count for specialists for i age, and j specialty, at k year
Let $L_{i,j,k}$ = Exit rate for specialists for i age, and j specialty at k year
Let $G_{j,k}$ = Entry volume for j specialty at k year
Let $A_{i,j,k}$ = Entry age distribution for i age, and j specialty at k year

Let $H_{i,j,k}$ = Expected number of specialists in Head Count (HC) for i, and j after k year(s)
Let $F_{i,j,k}$ = Expected number of specialists in Full Time Equivalent (FTE) for i, and j after k year(s)

Calculation of aging of the workforce and workforce flow in the model

Number of pre-existing specialists after k year(s) can be calculated by

$$\text{for } i = 21 \text{ to } 74, \text{ and } k = 1 \text{ to } 10 \qquad O_{i,j,k} = O_{i-1,j,k-1} \times \left(1 - L_{i-1,j,k-1}\right)$$

$$\text{for } i = 75+, \text{ and } k = 1 \text{ to } 10 \qquad O_{i,j,k} = O_{i-1,j,k-1} \times \left(1 - L_{i-1,j,k-1}\right) + O_{i,j,k-1} \times \left(1 - L_{i,j,k-1}\right)$$

Number of new, and re-entered specialists remain after k year(s) can be calculated by

$$\text{for } i = 20, \text{ and } k = 1 \text{ to } 10 \qquad E_{i,j,k} = G_{j,k} \times A_{i,j,k}$$

$$\text{for } i = 20 \text{ to } 74, \text{ and } k = 1 \text{ to } 10$$
$$E_{i,j,k} = G_{j,k} \times A_{i-1,j,k-1} \times \left(1 - \frac{L_{i-1,j,k-1}}{2}\right) + E_{i-1,j,k-1} \times \left(1 - L_{i-1,j,k-1}\right)$$

$$\text{for } i = 75+, \text{ and } k = 1 \text{ to } 10$$
$$E_{i,j,k} = G_{j,k} \times A_{i-1,j,k-1} \times \left(1 - \frac{L_{i-1,j,k-1}}{2}\right) + E_{i-1,j,k-1} \times \left(1 - L_{i-1,j,k-1}\right) +$$

$$+ E_{i,j,k-1} \times (1 - L_{i,j,k-1})$$

Expected number of specialists in Head Count (HC) for i, and j after k year(s) can be calculated by

$$H_{i,j,k} = O_{i,j,k} + E_{i,j,k}$$

Expected number of specialists in Full Time Equivalent (FTE) for i, and j after k year(s) can be calculated by

$$F_{i,j,k} = H_{i,j,k} \times R_{i,j,k}$$

Total number of specialists for j specialty after k year(s) in HC can be calculated by

$$\sum_{i=20}^{75+} H_{i,j,k}$$

Total number of specialists for j specialty after k year(s) in FTE can be calculated by

$$\sum_{i=20}^{75+} F_{i,j,k}$$

General assumptions

As the focus of this paper is to introduce the model, the model only uses base scenarios that are based on findings from 2011 to 2016 patterns of inflow and outflow volumes. The model forecasts specialty workforces for 36 vocational medical specialties for next 10 years in HCs and FTEs. The model also looks at number of doctors per 100,000 general population, and per 60+ age population for the next 10 year from the 2016 year. Population data was sourced from Statistics New Zealand's population projections, which were based on the 2013 census and updated in 2016. The model has projected how many specialty workforces may have lower number of specialists per 100,000 population or 100,000 60+ age population compared to 2016.

Results

Using General Surgery as an example, the ratio of specialists per 100,000 population is declining from 7.2 FTE, 5.7 HC in 2016 to 6.8 FTE, 5.5 HC in 2026 as shown in table 2. The ratio of specialists per 100,000 60+ age group population is declining even faster due to the aging population as shown in table 3.

Table 1 - Forecasted number (HC and FTE) of medical specialists

	Current and forecasted specialists (HC)			Current and forecasted specialists (FTE)		
Medical specialty	**2016**	**2021**	**2026**	**2016**	**2021**	**2026**
Anaesthesia	771	902	1004	869	1007	1109
Cardiothoracic Surgery	28	27	24	31	31	29
Clinical Genetics	15	19	23	14	12	14
Dermatology	66	73	76	69	75	75
Diagnostic & Interventional Radiology	452	555	627	476	586	660
Emergency Medicine	248	328	395	255	338	406
Family Planning & Reproductive Health	22	21	20	11	13	9
General Practice	3444	3871	4133	2960	3309	3502
General Surgery	268	275	281	336	344	349
Intensive Care Medicine	91	114	135	118	149	177
Internal Medicine	1009	1180	1314	1155	1348	1500
Medical Administration	29	37	39	30	37	37
Musculoskeletal Medicine	20	19	17	23	23	20
Neurosurgery	23	24	25	30	33	35
Obstetrics & Gynaecology	292	335	362	327	374	402
Occupational Medicine	57	57	57	58	58	57
Ophthalmology	137	147	153	144	155	158
Oral & Maxillofacial Surgery	23	29	35	23	29	36
Orthopaedic Surgery	273	296	311	342	372	383
Otolaryngology Head & Neck Surgery	109	112	113	118	119	119
Paediatric Surgery	18	19	21	27	28	30
Paediatrics	369	424	464	398	454	495
Pain Medicine	25	34	42	25	35	43
Palliative Medicine	53	58	60	52	54	56
Pathology	286	315	331	300	330	344
Plastic & Reconstructive Surgery	64	71	75	75	83	88
Psychiatry	572	635	675	584	644	678
Public Health Medicine	176	180	180	170	169	166
Radiation Oncology	65	77	81	79	94	97
Rehabilitation Medicine	23	27	30	24	29	29
Rural Hospital Medicine	109	124	133	89	90	86
Sexual Health Medicine	18	16	14	11	11	9
Sports Medicine	25	26	28	28	28	30
Urgent Care	162	248	309	150	237	291
Urology	63	63	63	79	77	77
Vascular Surgery	32	35	37	40	40	39

Table 2 - Forecasted number (HC and FTE) of medical specialists per 100,000 general population

	Current and forecasted specialists (HC)			Current and forecasted specialists (FTE)		
Medical specialty	**2016**	**2021**	**2026**	**2016**	**2021**	**2026**
Anaesthesia	16.5	18.3	19.6	18.6	20.4	21.6
Cardiothoracic Surgery	0.6	0.5	0.5	0.7	0.6	0.6
Clinical Genetics	0.3	0.4	0.5	0.3	0.2	0.3
Dermatology	1.4	1.5	1.5	1.5	1.5	1.5
Diagnostic & Interventional Radiology	9.7	11.3	12.2	10.2	11.9	12.9
Emergency Medicine	5.3	6.7	7.7	5.4	6.9	7.9
Family Planning & Reproductive Health	0.5	0.4	0.4	0.2	0.3	0.2
General Practice	73.6	78.5	80.5	63.2	67.1	68.2
General Surgery	5.7	5.6	5.5	7.2	7.0	6.8
Intensive Care Medicine	1.9	2.3	2.6	2.5	3.0	3.5
Internal Medicine	21.6	23.9	25.6	24.7	27.4	29.2
Medical Administration	0.6	0.8	0.8	0.6	0.7	0.7
Musculoskeletal Medicine	0.4	0.4	0.3	0.5	0.5	0.4
Neurosurgery	0.5	0.5	0.5	0.6	0.7	0.7
Obstetrics & Gynaecology	6.2	6.8	7.0	7.0	7.6	7.8
Occupational Medicine	1.2	1.2	1.1	1.2	1.2	1.1
Ophthalmology	2.9	3.0	3.0	3.1	3.1	3.1
Oral & Maxillofacial Surgery	0.5	0.6	0.7	0.5	0.6	0.7
Orthopaedic Surgery	5.8	6.0	6.1	7.3	7.5	7.5
Otolaryngology Head & Neck Surgery	2.3	2.3	2.2	2.5	2.4	2.3
Paediatric Surgery	0.4	0.4	0.4	0.6	0.6	0.6
Paediatrics	7.9	8.6	9.0	8.5	9.2	9.6
Pain Medicine	0.5	0.7	0.8	0.5	0.7	0.8
Palliative Medicine	1.1	1.2	1.2	1.1	1.1	1.1
Pathology	6.1	6.4	6.4	6.4	6.7	6.7
Plastic & Reconstructive Surgery	1.4	1.4	1.5	1.6	1.7	1.7
Psychiatry	12.2	12.9	13.2	12.5	13.1	13.2
Public Health Medicine	3.8	3.7	3.5	3.6	3.4	3.2
Radiation Oncology	1.4	1.6	1.6	1.7	1.9	1.9
Rehabilitation Medicine	0.5	0.5	0.6	0.5	0.6	0.6
Rural Hospital Medicine	2.3	2.5	2.6	1.9	1.8	1.7
Sexual Health Medicine	0.4	0.3	0.3	0.2	0.2	0.2
Sports Medicine	0.5	0.5	0.5	0.6	0.6	0.6
Urgent Care	3.5	5.0	6.0	3.2	4.8	5.7
Urology	1.3	1.3	1.2	1.7	1.6	1.5
Vascular Surgery	0.7	0.7	0.7	0.9	0.8	0.8

Table 3 - Forecasted number (HC and FTE) of medical specialists per 100,000 population aged 60+

	Current and forecasted specialists (HC)			Current and forecasted specialists (FTE)		
Medical specialty	**2016**	**2021**	**2026**	**2016**	**2021**	**2026**
Anaesthesia	79.9	79.8	77.5	90.1	89.0	85.6
Cardiothoracic Surgery	2.9	2.4	1.9	3.2	2.7	2.2
Clinical Genetics	1.6	1.7	1.8	1.5	1.1	1.1
Dermatology	6.8	6.4	5.8	7.2	6.6	5.8
Diagnostic & Interventional Radiology	46.9	49.1	48.4	49.3	51.8	50.9
Emergency Medicine	25.7	29.0	30.5	26.4	29.9	31.3
Family Planning & Reproductive Health	2.3	1.8	1.6	1.1	1.2	0.7
General Practice	357.1	342.3	318.9	306.9	292.6	270.2
General Surgery	27.8	24.3	21.7	34.9	30.4	27.0
Intensive Care Medicine	9.4	10.1	10.4	12.3	13.2	13.7
Internal Medicine	104.6	104.3	101.4	119.8	119.2	115.7
Medical Administration	3.0	3.3	3.0	3.1	3.3	2.9
Musculoskeletal Medicine	2.1	1.7	1.3	2.4	2.1	1.5
Neurosurgery	2.4	2.1	2.0	3.1	2.9	2.7
Obstetrics & Gynaecology	30.3	29.6	27.9	33.9	33.0	31.0
Occupational Medicine	5.9	5.1	4.4	6.0	5.1	4.4
Ophthalmology	14.2	13.0	11.8	14.9	13.7	12.2
Oral & Maxillofacial Surgery	2.4	2.6	2.7	2.4	2.6	2.8
Orthopaedic Surgery	28.3	26.2	24.0	35.5	32.9	29.5
Otolaryngology Head & Neck Surgery	11.3	9.9	8.8	12.2	10.5	9.2
Paediatric Surgery	1.9	1.7	1.6	2.8	2.5	2.3
Paediatrics	38.3	37.5	35.8	41.3	40.2	38.2
Pain Medicine	2.6	3.0	3.3	2.6	3.1	3.3
Palliative Medicine	5.5	5.1	4.6	5.4	4.8	4.3
Pathology	29.7	27.9	25.5	31.2	29.2	26.5
Plastic & Reconstructive Surgery	6.6	6.3	5.8	7.8	7.3	6.8
Psychiatry	59.3	56.1	52.1	60.6	56.9	52.3
Public Health Medicine	18.2	16.0	13.9	17.6	15.0	12.8
Radiation Oncology	6.7	6.8	6.3	8.2	8.3	7.5
Rehabilitation Medicine	2.4	2.3	2.3	2.5	2.5	2.3
Rural Hospital Medicine	11.3	11.0	10.2	9.2	8.0	6.7
Sexual Health Medicine	1.9	1.4	1.1	1.1	0.9	0.7
Sports Medicine	2.6	2.3	2.1	2.9	2.5	2.3
Urgent Care	16.8	21.9	23.8	15.6	20.9	22.5
Urology	6.5	5.6	4.9	8.1	6.8	5.9
Vascular Surgery	3.3	3.1	2.9	4.1	3.5	3.0

Discussions

Since August 2015, the forecasting model and input parameters have been validated with many medical colleges (such as the Royal New Zealand College of General Practitioners), specialty society groups, and other government entities for their corresponding specialties and interest.

We also have tested the model with historic data to forecast and compare against the actual data. For the test, we used the combined total medical vocational specialty workforce (excluding General Practice) in 2012 to 2016. The test was conducted to validate the calculation of the model. We purposely selected a large workforce sample as it would be more likely to have evenly distributed age within each age group. The forecast results are very close to the actual data as shown in the table 4, and results are within plus minus 1 %.

Table 4. Medical specialty workforce projection using the historic data demonstrating accurate model in comparison to actual data.

Year	2012	2013	2014	2015	2016
Actual	4891	5055	5327	5579	5804
Forecasted	4870	5052	5326	5554	5755
Difference in Percentage	-0.4%	-0.1%	0.0%	-0.4%	-0.8%

Should a specialty group be small, the forecasting accuracy would naturally deteriorated. There are some specialties, such as paediatrics or paediatric surgeries, that are not appropriate to compare against the 60+ age population.

The main objective of the development of the model and the model was to predict volume and age distribution of each medical specialty workforce supply. New Zealand medical workforce supply has always been highly influenced by immigration policies in New Zealand and immigration policies in other English speaking countries with many push and pull factors [10]. One of major difficulties of health workforce planning is that there are many influencing factors, such as economics, labour market, social, demographic, and immigration policies. The combined influences of those factors can now be measured by tracking individual doctor's APC renewal patterns, and using these APC renewal patterns to predict the future size of a workforce. Knowing the future age distribution of a workforce also helps training organisations and government agencies understand whether current trainee workforces are meeting future demand. The impact of new policies on a workforce can be tested by changing the FTE per HC ratio, entry/re-entry volume, exit rates for each future year for every age and specialty in the model.

Limitations

The forecasting model focuses on the supply side of the workforces and uses population projections as a proxy for future workforce demand. However, demand analysis must also consider future models of care that can produce optimal outcomes at lower cost [11].

Understanding demand volume, such as consultations or procedures to be delivered by each specialty, can also help inform future requirements. Therefore, construction of matching demand model will increase the usefulness of the forecasting model.

The number of doctors per 100,000 general population, and per 60+ age population for 10 years from 2016 can mislead readers as it does not show whether a current workforce is already experiencing shortages. An upward trend in workforce supply can reflect the health sector's past responses to address workforce shortages, such as by recruiting overseas-trained doctors. Therefore, the results of the model should always be interpreted with other non-quantifiable information for better understanding of the situation at hand.

The results presented in this paper are a snapshot of how workforce patterns in 2012 to 2016 can impact the future workforce. The HC and FTE projections presented in the results will change as subsequent versions of the forecasting model incorporate updated data.

Conclusions

The model has opened a new way of using routinely collected APC data for evidence-informed health workforce planning and policy development. The age distribution of the future workforce is particularly useful to decide training volumes for the future. The projections from the model facilitates discussions with the health sector about potential solutions for the future medical specialty workforces. The model is easily applicable to other workforces in other settings and countries, and also easily scalable for a geographical regions as long as there is access the APC information for those geographical regions is accessible. The model provides invaluable insight of future workforce supply projections.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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