Ten year trends in cardiac implantable electronic devices in New Zealand: a national data linkage study (ANZACS-QI 51).

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Abstract

Introduction Implant rates for cardiac implantable electronic devices (CIED), including permanent pacemakers (PPM) and implantable cardioverter defibrillators (ICD), have increased globally in recent decades. This is the first national study providing a contemporary analysis of national CIED implant trends by sex-specific age groups over an extended period. Methods Patient characteristics and device type were identified for ten years (2009 to 2018) using procedure coding in the National Minimum Datasets, which collects all New Zealand (NZ) public hospital admissions. CIED implant rates represent implants/million population. Results New PPM implant rates increased by 4.6%/year (p<0.001), increasing in all age groups except patients <40 years. Males received 60.1% of new PPM implants, with higher implant rates across all age groups compared to females. The annual increase in age-standardised implant rates was similar for males and females (3.4% vs 3.0%, p=0.4). By 2018 the overall PPM implant rate was 538/million. New ICD implant rates increased by 4.2%/year (p<0.001), increasing in all age groups except patients <40 and [?]80 years. Males received 78.1% of new ICD implants, with higher implant rates across all age groups compared to females. The annual increase in age-standardised implant rates was higher in males compared to females (3.5% vs 0.7%, p<0.001). By 2018 the overall ICD implant rate was 144/million population. Conclusion CIED implant rates have increased steadily in NZ over the past decade but remain low compared to international benchmarks. Males had substantially higher CIED implant rates compared to females, with a growing gender disparity in ICD implant rates.

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Methods

Patient characteristics and device type were identified for ten years (2009 to 2018) using procedure coding in the National Minimum Datasets, which collects all New Zealand (NZ) public hospital admissions. CIED implant rates represent implants/million population.

Results

New PPM implant rates increased by 4.6%/year ($p<0.001$), increasing in all age groups except patients <40 years. Males received 60.1% of new PPM implants, with higher implant rates across all age groups compared to females. The annual increase in age-standardised implant rates was similar for males and females (3.4% vs 3.0%, $p=0.4$). By 2018 the overall PPM implant rate was 538/million.

New ICD implant rates increased by 4.2%/year ($p<0.001$), increasing in all age groups except patients <40 and [?]80 years. Males received 78.1% of new ICD implants, with higher implant rates across all age groups compared to females. The annual increase in age-standardised implant rates was higher in males compared to females (3.5% vs 0.7%, $p<0.001$). By 2018 the overall ICD implant rate was 144/million population.

Conclusion

CIED implant rates have increased steadily in NZ over the past decade but remain low compared to international benchmarks. Males had substantially higher CIED implant rates compared to females, with a growing gender disparity in ICD implant rates.

Keywords: permanent pacemaker, implantable cardioverter defibrillator, trends, sex, gender, age, New Zealand

Introduction

Globally, the rate of cardiac implantable electronic devices (CIED) implants has increased over the past few decades as the population has grown and the indications for device implantation have broadened.[1,2] CIEDs include permanent pacemakers (PPM) and implantable cardioverter defibrillators (ICD). PPM are generally indicated for the management of bradyarrhythmias. ICD are indicated for the primary prevention of sudden cardiac death in patients with symptomatic heart failure and left ventricular ejection fraction (LVEF) [?]35% despite optimal medical therapy.[3–12] They are also indicated for secondary prevention of sudden cardiac death in patients who have survived a cardiac arrest or haemodynamically unstable ventricular arrhythmia.[3,13–16] Several studies have shown that the mean age at new implant for both PPM and ICD is increasing.[17–20] Multiple international and local studies have also demonstrated that there is a significant difference in CIED implant rates by sex, particularly for ICDs.[2,19–32] However, there is limited published data on implant trends by sex-specific age groups. We aimed to provide a contemporary analysis of CIED implant trends by age and sex over the past decade in New Zealand.

Methods

All patients who received a PPM or ICD implant were identified in the National Minimum Dataset (which collects data on all public hospital admissions in New Zealand) for the period of 1stJanuary 2009 to 31st December 2018 using International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD10-AM) procedure codes and applying specific prioritisation and categorisation rules (Appendix table A.1).[33] This methodology was validated against the All New Zealand Acute Coronary Syndrome Quality Improvement Cardiac Implanted Device Registry (ANZACS-QI DEVICE) in a previous analysis, showing an excellent ability to capture all CIED implants nationally and differentiate between PPM and ICD implants as well as new and replacement procedures.[34] National Minimum Dataset procedure codes are not collected from private hospitals. Additionally, CIED implants are very rarely performed at private hospitals as they are not covered by health insurance policies in New Zealand. Total PPM or ICD included new and replacement procedures. PPM implant rates include cardiac resynchronisation therapy pacemakers and ICD implant rates include cardiac resynchronisation therapy defibrillators. Several measures of implant rates were utilised: implant rates per million population; age-specific implant rates; and age-standardised implant rates to enable direct comparisons by gender.[35]

Statistical analysis

Implant rates per million population were calculated using the number of PPM or ICD implants as the numerator and the population projections for New Zealand for each year as the denominator. The 2018 New Zealand Population Projections are available from Statistics New Zealand. The difference in mean age of new CIED implants was evaluated using the non-parametric Mann-Whitney U test as the data was not normally distributed. Age-specific rates were calculated for men and women for the age groups <40, 40-59, 60-69, 70-79 and [?]80 years. The age-specific average annual percentage change in implant rates were calculated using Poisson regression. Implant rates were age-standardised using the direct method using the European Standard Population as the standard population.[35] Data was analysed using the SAS statistical package, version 9.4 (SAS Institute, Cary, NC). Trend analysis of age-standardised implant rates by sex was performed using the joinpoint regression model, which is useful in analysing varying trends over time.[36] Different line segments in the trend data are connected at "joinpoints". The model uses the trend data to fit the simplest joinpoint model that the data allows and tests whether more joinpoints are statistically significant. This was performed with the Joinpoint Regression Program, Version 4.7.0.0 - February 2019; Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute.

Ethics

This is an ANZACS-QI sub-study, which is part of the wider Vascular Informatics, Epidemiology and the Web (VIEW) study. The VIEW study was approved by the Northern Region Ethics Committee Y in 2003 (AKY/03/12/314), with subsequent amendments to include the ANZACS-QI registries, and with annual approvals by the National Multi-region Ethics Committee since 2007 (MEC07/19/EXP).

Results:

Permanent pacemakers

A total of 21,671 PPMs were implanted between 2009 and 2018. There was a steady increase in PPM implant volume and implant rate per million population over the study period. The total PPM implant volume increased by 55.4% (from 1,691 implants in 2009 to 2,627 implants in 2018). The total PPM implant rate per million increased by 36.9% (from 393 to 538 per million) at an average annual percentage increment of 3.8% (95% CI: 3.5 to 4.0%, p<0.001). (Appendix table A.2) There were 16,655 (76.9%) new PPM implants. The new PPM implant volume increased by 68.8% (from 1,242 to 2,096 implants). The new PPM implant rate per million increased by 48.4% (from 289 to 429 per million) at an average annual percentage increment of 4.6% (95% CI: 4.0 to 5.1%, p<0.001). (Table 1)

The mean age of patients receiving new PPM implants was 73.4 years in 2009 and 74.9 years in 2018 (p=0.137). Over the ten year period, patients older than 60 years accounted for 89.9% of all new implants. Patients aged 70-79 years (2009: 1,669/million, 2018: 2,239/million) and [?]80 years (2009: 3,451/million, 2018: 4,678/million) had the highest new PPM implant rates per million. There was an increase in implant rates in almost all age groups apart from patients <40 years (p=0.225). The highest age-specific average annual percent increase was in patients 40-59 years at 3.8% (95% CI: 1.9 to 5.7%, p<0.001) and patients [?]80 years at 3.7% (95% CI: 2.8 to 4.6%, p<0.001). (Table 1, Appendix table A.3)

Of the new PPM implanted during the study period, 10,003 patients (60.1%) were male. Male patients had higher implant rates than female patients throughout the study period. This difference was consistent across all age groups when analysed by sex-specific age groups. (Figures 1A, 1B) There was a similar overall increase in new PPM implants per million in both males and females (49.7% vs 46.3%) over the study period. The highest age-specific average annual percent increase in males was in the age group of [?]80 years at 3.9% (95% CI: 2.7 to 5.1%, p<0.001) while in females it was in the age group of 40-59 years at 6.4% (95% CI: 3.3 to 9.6%, p<0.001). (Table 2) Males had higher age-standardised implant rates than females, ranging from 1.7-fold higher in 2015 to 2.0-fold higher in 2017. The age-standardised implant rates increased by 3.4% per year (95% CI: 2.4 to 4.4%) in males and 3.0% (95% CI: 2.4 to 3.6%) in females. The difference in average annual percent increase between the two groups was not statistically significant (p=0.4). (Figure 2)

Implantable Cardioverter Defibrillators

A total of 5,897 ICD were implanted over the study period, with a steady increase in ICD implant volumes and implant rate per million population. The total ICD implant volumes increased by 59.0% (from 441 implants in 2009 to 701 implants in 2018). This translated to an increase in total ICD implant rate per million population of 39.8% (from 103 to 144 per million) at an average annual percentage increment of 4.5% (95% CI: 4.1 to 4.9%, p<0.001). (Appendix table A.2) There were 4,265 (72.3%) new ICD implants. The new ICD implant rate per million increased by 34.6% (from 78 to 105 per million) at an average annual percentage increment of 4.2% (95% CI: 3.3 to 5.2%, p<0.001). (Table 1)

The mean age of patients receiving new ICD implants was 57.4 years in 2009 and 59.3 years in 2018 (p=0.056). Over ten years, patients aged 40-79 years accounted for 87.9% of new ICD implants. Patients aged 60-69 years (2009: 239/million, 2018: 312/million) and 70-79 years (2009: 257/million, 2018: 333/million) had the highest new ICD implant rate per million. There was an increase in implant rates in almost all age groups apart from patients <40 years (p=0.358) and [?]80 years (p=0.054). The highest age-specific average annual percent increase was in patients 60-69 years at 4.0% (95% CI: 2.3 to 5.8%, p<0.001) and patients 40-59 years at 3.9% (95% CI: 2.3 to 5.5%, p<0.001). Patients [?]80 years did have an average annual percent increase that trended towards significance at 6.2% (95% CI: -0.1 to 12.9%, p=0.054), but only accounted for a very small proportion of implants over ten years (2.4%). (Table 1, Appendix table A.3)

Of the new ICD implants during the study period, 3,353 patients (78.6%) were male. Males had higher implant rates than females throughout the study period. This difference was consistent across all age groups when analysed by sex-specific age groups. (Figures 3A, 3B) Males also had a higher overall increase in

implant rate per million compared to females (39.1% vs 14.5%) over the study period. The highest age-specific average annual percent increase in males was in the age group of [?]80 years at 9.2% (95% CI: 1.4 to 17.5%, p=0.020) while in females it was in the age group of 40-59 years at 3.7% (95% CI: 0.4 to 7.1%, p=0.026). As above, ICD implants in males [?]80 years only accounted for a very small number of ICD implants over the study period (2.2%). The second highest age-specific average annual percent increase in males was in the age group of 60-69 years at 5.0% (95% CI: 3.1 to 7.0%, p<0.001). Males had a higher average annual percent increase in all age groups apart from the age group 70-79. (Table 2) The age-standardised implant rates were substantially higher for males compared to females. This was lowest at 3.6-fold in 2013, and highest at 5.2-fold in 2018. The age-standardised implant rates increased by 3.5% per year (95% CI: 2.1 to 5.0%) in males and remained static at 0.7% (95% CI: -1.6 to 3.1%) in females. The difference in average annual percent increase between the two groups was statistically significant (p<0.001). (Figure 2)

Discussion

To our knowledge this is the first description of national CIED implant trends with detailed analysis by sex-specific age groups over an extended time period. Over ten years there has been a steady increase in new CIED implant rates in New Zealand, both for PPMs and ICDs, with an increase in almost all age groups. Men had higher CIED implant rates than women. Although PPM implant rates increased similarly for both men and women, ICD implant rates increased only in men.

Age-specific trends

There was an increase in new PPM implants in all age groups apart from the youngest age group, and as discussed below, the growth in PPM implant rates in New Zealand exceed recent international trends. Changes in population demographics and disease burden in New Zealand are unlikely to have been very different from other high income countries, therefore the large increase in PPM implant rates is most likely due to improved patient access to device implantation and to lower clinical thresholds for referral for pacemaker implantation. These include lower thresholds for less robust PPM indications such as symptomatic sinus node dysfunction, vagal-mediated syncope and syncope with ECG evidence of bifascicular block or significantly prolonged PR interval; as well as a willingness to perform implants in patients with advanced age or frailty.

ICD implant rates have also increased in almost all age groups apart from the youngest and oldest age groups. The growth in ICD implants is likely to represent improved survival of heart failure patients with the use of medical therapy, as well as improved access and resources for guideline-directed device therapy, despite the declining incidence of acute coronary syndrome in New Zealand.[3,12,37,38]

The mean ages of PPM (74.4 years) and ICD (59.2 years) implants are in keeping with those reported in international studies.[26–30] However, there was only a small and non-significant increase in the mean age of patients receiving implants over the study period, which differs from the increasing mean age reported in other international studies.[17-20]

Sex differences

Males accounted for 60.1% of new PPM implants and 78.6% of new ICD implants. The proportion of males receiving PPM are comparable to previous reports in international and local studies.[20–22,25,26] There was also a comparable average annual percentage increase in new PPM implants in both men and women. The gender disparity in ICD implants have been reported in multiple studies.[19,20,22–24,27–32] However, there was a higher average annual percent increase in new ICD implants for males as compared to females in almost all age-groups, which has not previously been reported.[24,42] Our colleagues have recently shown that despite the overall decline in hospitalisation for acute coronary syndrome for both sexes over the past decade, men continued to have higher hospitalisation rates for acute coronary syndrome compared to women.[38] This may have led to a higher prevalence of ischaemic cardiomyopathy in males. This notion is supported by a recent local study in New Zealand, which demonstrated that women receiving an ICD are more likely to have non-ischaemic cardiomyopathy than men.[30] The effectiveness of primary prevention ICD in women also remains unclear, with multiple studies showing conflicting results.[43–45] Women presenting with

non-ischaemic cardiomyopathy in New Zealand may therefore be less likely to be offered an ICD. Women with cardiomyopathy and left bundle branch block have also been shown to derive greater benefit from cardiac resynchronisation therapy devices compared to men and may be more likely to be offered a cardiac resynchronisation therapy pacemaker rather than a cardiac resynchronisation therapy defibrillator in New Zealand.[46–48] Further studies are needed to understand these sex differences.

Comparisons with international implant rates and trends

The total PPM and ICD implant rates per million in New Zealand have increased by a similar proportion over the past decade (36.9% and 39.8%, respectively). The growth in New Zealand ICD implant rates are comparable to the growth seen in the European Union (42%) over the decade between 2007 and 2016.[1] In contrast, the growth in PPM implant rates in New Zealand far outpaced the European Union (12%) over the same period.[1] Despite this, the New Zealand PPM and ICD implant rates in 2016 remained well below the European Union and countries with comparable healthcare expenditure per capita such as the United Kingdom, Italy and Finland. Within the Asia Pacific region, New Zealand is second only to Australia in CIED implant rates.[1,39–41] (Table 3)

Limitations:

This study is a descriptive analysis of implant volumes and rates in New Zealand using ICD10-AM coding. This study has not investigated underlying disease burden, ethnic, geographical or socioeconomic factors that may have impacted on implant rates. The ICD10-AM procedure codes were not able to reliably differentiate primary from secondary prevention ICD implants.

Conclusion:

CIED implants, both PPM and ICDs, have increased steadily in New Zealand over the past decade, and the increase in almost every age group indicates that it is not simply a reflection of an ageing population. Despite this, New Zealand implant rates of international guideline appropriate CIED therapy remain low compared to international benchmarks. Men had substantially higher CIED implant rates compared to women, with a growing gender disparity in ICD implant rates.

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Figure Legends:

Figure 1A: New PPM implant rates by age group in male patients. Excludes replacement procedures. PPM, permanent pacemaker.

Figure 1B: New PPM implant rates by age group in female patients. Excludes replacement procedures. PPM, permanent pacemaker.

Figure 2: Average annual percent change of new PPM and ICD age-standardised implant rate per million by sex 2009-2018. Excludes replacement procedures. AAPC, average annual percentage change; CI, confidence interval; ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.

Figure 3A: New ICD implant rates by age group in male patients. Excludes replacement procedures. ICD, implantable cardioverter defibrillator.

Figure 3B: New ICD implant rates by age group in female patients. Excludes replacement procedures. ICD, implantable cardioverter defibrillator.

Figures:

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Figure 1A: New PPM implant rates by age group in male patients. Excludes replacement procedures. PPM, permanent pacemaker.

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Figure 1B: New PPM implant rates by age group in female patients. Excludes replacement procedures. PPM, permanent pacemaker.

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Figure 2: Average annual percent change of new PPM and ICD age-standardised implant rate per million by sex 2009-2018. Excludes replacement procedures. AAPC, average annual percentage change; CI, confidence interval; ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.

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Figure 3A: New ICD implant rates by age group in male patients. Excludes replacement procedures. ICD, implantable cardioverter defibrillator.

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Figure 3B: New ICD implant rates by age group in female patients. Excludes replacement procedures. ICD, implantable cardioverter defibrillator.

Tables:

Device type	Age groups (years)	2009 implants/million	2018 implants/million	AAPC % (95% CI)
New PPM	Overall	289	429	4.6% (4.0 to 5.1%)
	<40 40-59 60-69 70-79 [?]80	16 92 519 1,669 3,451	14 146 619 2,239 4,678	-2.4% (-6.1 to 1.5%) 3.8% (1.
New ICD	Overall	78	105	4.2% (3.3 to 5.2%)
	<40 40-59 60-69 70-79 [?]80	21 118 239 257 56	27 147 312 333 63	1.4% (-1.5 to 4.4%) 3.9% (2.3

Table 1: Average annual percentage change in new PPM and ICD implants by age group. Excludes replacement procedures. AAPC, average annual percentage change; CI, confidence interval; ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker. Detailed age-specific implant rates 2009-2018 are available in Appendix table A.3

Device type	Age groups (years)	Male, AAPC % (95% CI)	p-value	Female, AAPC % (95% CI)	p-value
New PPM	<40 40-59 60-69 70-79 [?]80	-3.1% (-8.0 to 2.1%) 2.2% (-0.2 to 4.6%) 3.1% (1.4 to 4.8%) 3.2% (2.0 to 4.5%) 3.9% (2.7 to 5.1%)	0.240 0.073 <0.001 <0.001 <0.001	-1.6% (-7.1 to 4.4%) 6.4% (3.3 to 9.6%) 2.7% (0.5 to 5.0%) 2.9% (1.3 to 4.4%) 2.8% (1.5 to 4.1%)	0.601 <0.001 0.015 <0.001 <0.001
New ICD	<40 40-59 60-69 70-79 [?]80	2.1% (-1.5 to 5.8%) 4.0% (2.2 to 5.9%) 5.0% (3.1 to 7.0%) 2.5% (0.3 to 4.9%) 9.2% (1.4 to 17.5%)	0.259 <0.001 <0.001 0.028 0.020	-0.2% (-5.1 to 5.0%) 3.7% (0.4 to 7.1%) 0.1% (-3.8 to 4.2%) 2.7% (-2.1 to 7.7%) -2.7% (-13.3 to 9.1%)	0.938 0.026 0.963 0.274 0.636

Table 2: Average annual percent change in new PPM and ICD implants for sex-specific age groups. Excludes replacement procedures. AAPC, average annual percentage change; CI, confidence interval; ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.

	PPM*	ICD*
New Zealand	535	142
European Union (mean)	817	202
United Kingdom	784	222
Italy	1087	408
Finland	1163	304
Australia (2017)	888	254

Table 3: Comparative CIED implant rates per million population in 2016.[1,39,40] CIED, cardiac implantable electronic devices; ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker. *CIED implant rates included new and replacement devices. PPM implant rates include cardiac resynchronisation therapy pacemakers and all ICD implant rates include cardiac resynchronisation therapy defibrillators.

Appendix

PPM new	3827800, 3827801, 3828100, 3828101, 3828102, 3828103, 3828104, 3828105, 3828106, 3828107, 3828108,
PPM replacement	3835001, 3835301, 3836801
ICD new	3839001, 3839002, 3839300, 3852102, 3852103, 3852400
ICD replacement	3835003, 3836803, 3839301, 3852106, 3852110, 3852403

Table A.1: ICD10-AM codes for PPM and ICD implants. If codes for ICD and PPM were both present in a single episode of care (EoC), this was categorised as an ICD implant. When codes for a new and replacement procedure were both present in a single EoC, if the replacement procedure occurred on the same day or earlier than the new procedure date, this was categorised as a replacement procedure. Conversely, if the replacement procedure date was a day or more after the new procedure date, this procedure was categorised as a new implant. ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.

Year	PPM	PPM	PPM	PPM	ICD	ICD
	Implant volumes Total	Implant volumes New	Implant rate per million Total	Implant rate per million New	Implant volumes Total	Impl New
2009	1691	1242	393	289	441	334
2010	1803	1352	414	311	489	364
2011	1877	1438	428	328	465	328
2012	1941	1493	440	339	596	420
2013	2115	1608	476	362	613	421
2014	2209	1661	490	368	604	442
2015	2308	1729	502	376	624	439
2016	2511	1961	535	418	666	496
2017	2589	2075	540	433	698	510
2018	2627	2096	538	429	701	511

Table A.2: PPM and ICD implant volume and implant rate per million. ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.

	2009	2010	2011
New PPM <40 40-59 60-69 70-79 [?]80 Overall	19 92 519 1669 3451 289	8 111 553 1825 3650 311	14 115 559 1796 38
New ICD <40 40-59 60-69 70-79 [?]80 Overall	14 118 239 257 56 78	18 109 270 296 81 84	14 105 232 266 53

Table A.3: New PPM and ICD implant rate per million by age groups. ICD, implantable cardioverter defibrillator; PPM, permanent pacemaker.