Age- and Sex-Specific Trends in the Incidence of Hospitalized Acute Coronary Syndromes in Western Australia

Lee J. Nedkoff, BSc (Physiotherapy), MPH; Tom G. Briffa, BPhysEd, MPhysEd, PhD; David B. Preen, BSc (Hons), PhD; Frank M. Sanfilippo, BSc, BPharm, PGradDipPharm, PhD; Joseph Hung, MBBS, FRACP, FACC; Stephen C. Ridout, BSc (Hons); Matthew Knuiman, BSc (Hons), PhD; Michael Hobbs, MBBS, DPhil (Oxon), FRACP, FAFPHM

Background—The incidence of myocardial infarction has declined during the past 4 decades in many populations. However, there are limited population data measuring trends in acute coronary syndromes (ACS). We therefore examined temporal trends in the incidence of hospitalized ACS by age and sex in a population-based cohort.

Methods and Results—The Western Australian Data Linkage System, a repository of linked administrative health data, was used to identify 29 421 incident ACS hospitalizations between 1996 and 2007. Poisson log-linear regression models were used to calculate incidence rate changes. Age-standardized incidence rates of ACS declined annually in men by 1.7% (95% confidence interval [CI], −2.1 to −1.3) and in women by 1.6% (95% CI, −2.1 to −1.0). These declining rates were underpinned by annual reductions in the incidence of unstable angina (men, −3.0%; 95% CI, −3.7 to −2.4; women, −2.5; 95% CI, −3.3 to −1.7), whereas annual changes in myocardial infarction incidence were less (men, −1.0%; 95% CI, −1.5 to −0.5; women, −0.8%; 95% CI, −1.6 to 0). However, the overall trends masked age group differences, with ACS incidence increasing annually in 35- to 54-year-old women (2.3%; 95% CI, 1.0 to 3.8), predominantly driven by increasing incidence of myocardial infarction.

Conclusions—The age-standardized incidence of ACS decreased significantly in Western Australia from 1996 to 2007. However, an increase in ACS incidence in women ages 35 to 54 years is troubling and warrants further investigation. (Circ Cardiovasc Qual Outcomes. 2011;4:557-564.)

Key Words: acute coronary syndromes ■ incidence ■ epidemiology
were ≥35 years of age. Tertiary acute care of CHD is concentrated in the capital city, Perth, which has approximately 75% of the state’s population. Tertiary medical treatment of CHD for WA residents outside the state is rare. Data for this study were obtained from 2 core datasets of the WADLS, which routinely capture all public and private hospitalizations (Hospital Morbidity Data Collection, HMDC) and all registered deaths. Statutory obligations require all hospitals in WA to report standard data for every hospitalization. Multiple records for an individual are linked by key identifiers, using probabilistic matching, for which there is a high level of accuracy. Discharge diagnoses are coded in the HMDC in a principal diagnosis field and up to 20 secondary diagnosis fields, using the International Classification of Diseases (ICD) version current at the time. ICD-9 was used in WA from 1979, including the Clinical Modification (CM) from 1988 and Australian version from 1995, and ICD-10 Australian Modification (AM) since July 1, 1999. The dataset for this study contained all hospital and death records for patients hospitalized with a discharge diagnosis of CHD between January 1, 1986, and December 31, 2007, in WA. The study population was restricted to those 35 to 84 years of age because the diagnosis of ACS in the HMDC was considered unreliable in the very elderly.

**WHAT IS KNOWN**

- Long-term trends in the incidence of myocardial infarction have continued downward.
- Despite the contemporary shift in management toward defining acute events as acute coronary syndromes, there are limited population-based data available for trends incorporating unstable angina.

**WHAT THE STUDY ADDS**

- The incidence of acute coronary syndromes declined significantly in Western Australia from 1996 to 2007.
- This trend was driven by larger declines in unstable angina incidence than were seen for myocardial infarction.
- Declining trends in acute coronary syndrome incidence were observed across all age groups, except in 35- to 54-year-old women, in whom incidence was increasing.

### Event Classification

The primary outcome in this study was incident ACS hospitalization. ACS was identified when either MI (ICD-9-CM 410, ICD-10-AM I21) or UA (411.1, I20.0) was coded in the principal discharge diagnosis field. A case was designated as incident if there was no hospital admission for CHD (ICD-9/ICD-9-CM 410 to 414; ICD-10-AM I20-I25), coded in any diagnosis field, in the 10 years before the ACS admission. Incident ACS cases were considered nonfatal if the patient survived ≥28 days from the hospital admission date. Patients who were treated in, or died in, a hospital emergency department but were not admitted to hospital were not included in the study population. Comorbidities were identified from principal or secondary diagnosis fields within the 5 years before the incident admission or if coded in a secondary diagnosis field on the incident admission. Comorbid conditions were identified by the following ICD codes: diabetes (ICD-9-CM 250, ICD-10-AM E10-E14); chronic renal failure (585, N18); stroke (430, 431, 433.x1, 434.x1, 436, I60, I61, I63, I64); peripheral arterial disease (440 to 444, 447, 448, I70-I79); heart failure (428, 150); atrial fibrillation (427.3, 148); hypertension (401 to 405, I10-I15); rheumatic heart disease (390 to 398, I00-I09); cancer (140 to 239, C00-C96); and chronic obstructive pulmonary disease (490 to 496, J40-J47).

### Statistical Analysis

Differences in characteristics of ACS patients were evaluated using a $\chi^2$ test for categorical variables and linear regression for temporal trends in continuous variables by sex. Incidence rates were calculated separately for men and women. Annual age-standardized and age-specific incidence rates were calculated for ACS, MI, and UA, using the number of events for each group in each year as the numerator and the WA population in each group for that year as the denominator. Rates were standardized by 5-year age groups, using the WA population from the 2006 census as the standard population.

Trends in incidence rates were examined using Poisson log-linear regression. Model fits were tested for overdispersion, and no evidence of this was found. Models for calculating trends in incidence rates included calendar year (continuous variable) and 5-year age groups (categorical variable). Separate models that included 5-year age groups, calendar year, and an interaction term (age group$x$year) were used to test the interaction between age group and calendar year. Relative changes in incidence rates with time were calculated by using the exponential of the $\beta$-coefficient for calendar year and are presented as the estimated annual change (in percent) during the study period. Data analysis was performed using SAS (version 9.2), and statistical significance was set at the 5% level. Ethics approval for this study was obtained from the University of Western Australia and Department of Health (WA) Human Research Ethics Committees.

### Results

There were 29,421 incident ACS hospitalizations in people 35 to 84 years of age in WA from 1996 to 2007, of which 19,601 (66.6%) were in men (Table 1). The significant majority of all incident ACS admissions were nonfatal (95.5%, $P<0.0001$), and in incident UA, >99% of cases were nonfatal ($P<0.0001$). The mean age (standard deviation) for incident MI in women was 68.2 years (SD, 11.7), compared with 65.2 years (SD, 11.5) for incident UA. In men, the mean age was 61.3 years (SD, 11.8) for incident ACS hospitalizations. Mean age in women with incident ACS fell by 2.6 years ($P<0.0001$) over the study period but was unchanged in men ($P=0.5$), and comparable trends for MI and UA were seen in both sexes. The comorbidities most frequently identified in
Those with an incident ACS hospitalization were hypertension (44.1%), diabetes (19.7%), heart failure (11.5%), and atrial fibrillation (9.8%). Patients 75 to 84 years of age comprised 21.5% of the total study population (Table 2).

**Trends in Age-Standardized Incidence Rates**

Age-standardized incidence rates of ACS fell significantly during the study period (Figure 1). In men, there was a consistent decline from 428 per 100 000 person-years in 1996 to 345 per 100 000 person-years in 2007. Corresponding rates in women fell from 201 per 100 000 person-years to 170 per 100 000 person-years. The age-standardized incidence for MI and UA declined in men, with incidence rates for MI on average twice as high as UA rates; however, in women, incidence rates of MI and UA were equivalent in 1996 but diverged in the latter half of the study period (Figure 1). The

### Table 2. Trends in the Incidence of Hospitalized Acute Coronary Syndromes, 1996 to 2007

<table>
<thead>
<tr>
<th>Age group</th>
<th>Incident Events, n</th>
<th>Annual % Change (95% CI)*</th>
<th>Incident Events, n</th>
<th>Annual % Change (95% CI)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 to 84 y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>12 751</td>
<td>−1.0 (−1.5 to −0.5)†</td>
<td>5295</td>
<td>−0.8 (−1.6 to 0)</td>
</tr>
<tr>
<td>UA</td>
<td>6850</td>
<td>−3.0 (−3.7 to −2.4)†</td>
<td>4525</td>
<td>−2.5 (−3.3 to −1.7)†</td>
</tr>
<tr>
<td>ACS</td>
<td>19 601</td>
<td>−1.7 (−2.1 to −1.3)†</td>
<td>9820</td>
<td>−1.6 (−2.1 to −1.0)†</td>
</tr>
<tr>
<td>Age group, 35 to 54 y</td>
<td>3920</td>
<td>−0.2 (−1.1 to +0.8)</td>
<td>829</td>
<td>+4.0 (+1.9 to +6.1)†</td>
</tr>
<tr>
<td>MI</td>
<td>2142</td>
<td>−2.5 (−3.7 to −1.3)†</td>
<td>920</td>
<td>+0.9 (+1.0 to +2.8)</td>
</tr>
<tr>
<td>UA</td>
<td>6062</td>
<td>−1.0 (−1.7 to −0.3)†</td>
<td>1749</td>
<td>+2.3 (+1.0 to +3.8)†</td>
</tr>
<tr>
<td>Age group, 55 to 64 y</td>
<td>3456</td>
<td>−0.4 (−1.4 to +0.5)</td>
<td>949</td>
<td>−1.6 (−3.4 to +0.3)</td>
</tr>
<tr>
<td>MI</td>
<td>1957</td>
<td>−2.5 (−3.7 to −1.2)†</td>
<td>1128</td>
<td>−3.1 (−4.7 to −1.5)†</td>
</tr>
<tr>
<td>UA</td>
<td>5413</td>
<td>−1.2 (−1.9 to −0.4)†</td>
<td>2077</td>
<td>−2.4 (−3.6 to −1.2)†</td>
</tr>
<tr>
<td>Age group, 65 to 74 y</td>
<td>3160</td>
<td>−1.5 (−2.5 to −0.5)†</td>
<td>1521</td>
<td>−2.2 (−3.6 to −0.7)†</td>
</tr>
<tr>
<td>MI</td>
<td>1800</td>
<td>−3.9 (−5.2 to −2.6)†</td>
<td>1304</td>
<td>−3.1 (−4.8 to −1.6)†</td>
</tr>
<tr>
<td>UA</td>
<td>4960</td>
<td>−2.4 (−3.2 to −1.6)†</td>
<td>2825</td>
<td>−2.6 (−3.6 to −1.6)†</td>
</tr>
<tr>
<td>Age group, 75 to 84 y</td>
<td>2215</td>
<td>−1.9 (−3.1 to −0.7)†</td>
<td>1996</td>
<td>−1.0 (−2.3 to +0.2)</td>
</tr>
<tr>
<td>MI</td>
<td>951</td>
<td>−2.7 (−4.5 to −0.9)†</td>
<td>1173</td>
<td>−3.3 (−4.9 to −1.7)†</td>
</tr>
<tr>
<td>UA</td>
<td>3166</td>
<td>−2.2 (−3.2 to −1.2)†</td>
<td>3169</td>
<td>−1.9 (−2.9 to −0.9)†</td>
</tr>
</tbody>
</table>

ACS indicates acute coronary syndromes; CI, confidence interval; MI, myocardial infarction; and UA, unstable angina.

*Trends represent the average annual change during the study period and are calculated from log-linear Poisson regression models.

†P<0.05.

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**Figure 1.** Age-standardized incidence rates of acute coronary syndromes (ACS), myocardial infarction (MI), and unstable angina (UA) in men (A) and women (B) 35 to 84 years of age, Western Australia, 1996 to 2007. An incident event was identified from hospital morbidity data, in which there was no admission for coronary heart disease in the previous 10 years.
annual change in age-standardized ACS incidence was similar in men (−1.7%; 95% confidence interval [CI], −2.1 to −1.3) and women (−1.6%; 95% CI, −2.1 to −1.0), principally driven by significant annual declines in UA incidence (men, −3.0%; 95% CI, −3.7 to −2.4; women, −2.5%; 95% CI −3.3 to −1.7) (Table 2 and Figure 1). Reductions in age-standardized incidence of MI were modest in both sexes, only reaching statistical significance in men.

Trends in Age-Specific Incidence Rates
Age-specific incidence rates of ACS showed differing trends by sex (Table 2 and Figure 2). There was no significant difference in the magnitude of decline between age groups in men (interaction term for year and age group, P=0.09). The corresponding overall interaction term in women was highly significant (P<0.0001). The interaction model showed that there were similar decreasing trends in ACS incidence in women 55 to 64, 65 to 74, and 75 to 84 years of age, but there was an increasing trend of 2.3% per year (95% CI, 1.0 to 3.8) in women 35 to 54 years of age, although incidence rates in this age group were low (44 per 100 000 person-years in 1996, 61 per 100 000 person-years in 2007).

Age-specific trends for MI in men revealed no change in the 2 younger age groups, whereas rates decreased in the 2 older age groups (Table 2 and Figure 3). The incidence of MI also decreased in women between 55 and 84 years of age, although it was only significant in 65- to 74-year-olds. In contrast, there was a marked annual increase in MI incidence of 4.0% (95% CI, 1.9 to 6.1) in women 35 to 54 years of age. Incidence rates for UA showed substantial annual declines in all age groups in both sexes (range, −2.5% to −3.9%), with the exception of 35- to 54-year-old women, in whom rates were unchanged (0.9% per year; 95% CI, −1.0 to 2.8) (Table 2 and Figure 4). Incidence rate ratios of MI to UA generally increased throughout the study period (Figure 5).
Discussion

This population-based study using state-wide record linkage identified 29,421 incident hospitalized ACS events in WA from 1996 to 2007. Our results demonstrate declining age-standardized incidence of ACS in men (1.7% per year) and women (1.6% per year). These changes in ACS incidence were driven predominantly by annual declines in UA incidence of 3.0% in men and 2.5% in women and less so by declines in MI incidence. We found a disturbing significant increase in the incidence of ACS, primarily MI, in younger women.

Temporal Trends in Age-Standardized ACS Incidence

Globally, there are few published studies measuring population trends in ACS incidence. Although trends in MI incidence have been reported in many Western populations, including in WA,¹⁻³,¹⁶,¹⁷ there is a lack of population data for UA. Furthermore, the contemporary shift of clinical management focus to ACS and the limited data on concomitant MI and UA incidence means that monitoring changes in MI and UA is paramount. The reduction in ACS incidence observed in our study is consistent with trends in first hospitalizations for suspected ACS in the Scottish population, although their trends were underpinned by substantial reductions in MI and rising angina rates.¹⁸ These trends were in contrast with those seen in our study and may be due to the inclusion of all angina admissions as well as the earlier time period (before the widespread introduction of troponin testing). Our results are in agreement with ACS trends reported in studies from North America,¹⁹,²⁰ which, although not measuring incidence, have reported declining hospital admission rates for ACS, with both describing falling UA rates and smaller declines in MI rates.

There is now reliable evidence that troponin testing increases the diagnosis of MI in suspected cases of ACS²¹⁻²³ and attenuates declining MI trends.²⁴,²⁵ Troponin testing was introduced in WA at the start of our study period and was used in >90% of suspected MI cases by 2001.²⁴ The small reduction in incidence rates of MI and increasing incidence rate ratios in our study are...
consistent with the effects of this change in clinical practice. Conversely, declining trends in UA may be accentuated by a corresponding increase in diagnosis of MI cases due to troponin testing, and the substantial declines in UA incidence in men and women in our study may partially reflect this. Because of some uncertainty of the degree of transference in diagnosis between MI and UA, the use of ACS as a primary end point more effectively captures the total spectrum of acute coronary events.

The significant reduction in ACS incidence described in our study follows reported improvements in major CHD risk factors throughout the 1980s and 1990s. Substantial reductions in the prevalence of hypertension in the Australian adult population have occurred over several decades. Concurrently, measured total cholesterol levels fell significantly in men by 0.024 mmol/L and in women by 0.030 mmol/L, and smoking prevalence decreased by 15% and 10% in men and women, respectively, in the Perth population between 1980 and 1999. Highlighting the importance of these changes is the link between reductions in MI incidence and risk factor improvements reported from the British Regional Heart Study. Although only including men, this study reported that falling levels of smoking, blood pressure, and cholesterol accounted for 46% of the reduction in incidence in this population between 1978 and 2004. Improvements in these risk factors have also contributed to declining CHD mortality rates, with decreasing smoking prevalence having the greatest impact in these studies. It is therefore likely that the overall declines in ACS incidence seen in our population continue to be driven by reductions in these and other cardiovascular risk factors, underpinned by primary prevention efforts.

Temporal Trends in Age-Specific ACS Incidence

The significant reduction in the incidence of ACS in those between 55 and 84 years of age and in younger men is encouraging. Declining hospitalization rates for MI and UA were also reported from US administrative data in those ≥65 years of age between 2002 and 2007. The annual rate reductions reported by these researchers (∼6% for MI and ∼10% for UA) were greater than those seen in the same age groups in our study, which may be a result of effective secondary prevention measures for recurrent ACS in the United States. Additionally, the rapid uptake of troponin testing in the early period of our study may partially explain the differing magnitude of declines. Although an upper age limit of 84 years is used in our study, it is unlikely to have affected trends because the proportion of incident ACS cases in those ≥85 years of age in our dataset is small (<10%), and the results reported by Chen et al indicate similar trends in those 65 to 84 years of age and the very elderly. Importantly, however, our age-specific analyses revealed an increase in ACS incidence in young women which would otherwise be masked by the reductions in age-standardized incidence. Underpinning the change in 35- to 54-year-old women is increasing MI incidence (4.0% per year) and unchanged UA incidence. By comparison, ACS incidence declined significantly in men 35 to 54 years of age, principally because of a significant decline in the incidence of UA. There have been previous reports of increasing MI incidence in women, reportedly driven by increasing risk in older women; however, more recent data from the same project reported no difference in trends in MI incidence by age or sex. The use of ACS as a primary end point appears to be crucial in women, particularly in this younger age group in which MI and UA rates are equivalent, providing a more accurate representation of the burden of acute CHD.

The significant increase in MI incidence in 35- to 54-year-old women in our study could in part be attributed to the impact of troponin testing. However, there is currently a paucity of published evidence showing a selective impact of troponin testing on this group, with most studies showing greater effects in older people and women overall. A previous study in WA estimated that the impact of troponin testing on the relative increase in hospital admission rates for MI was greater in 35- to 64-year-old women compared with 65- to 79-year-old women, although the effect was still smaller than that seen in men in both age groups. However, no impact of troponin testing on trends in 28-day case-fatality rates in men or women was found. Additionally, increased clinician awareness of ACS in women may have resulted in greater numbers of events being diagnosed. The availability of a biomarker with increased sensitivity and specificity may accentuate this effect, although whether the adverse results in younger women in our study reflect this is uncertain.

The lack of concomitant decline in incidence of UA in women of this age group also supports a real increase in ACS. Additionally, WA data over the same period show similar age-specific trends in incidence of fatal coronary events, with declining rates in 55- to 84-year-olds not replicated in 35- to 54-year-olds, in whom rates are stable. There is also evidence that the 10-year risk for incident cardiovascular disease has not reduced at the same rate in women as it has in men in the decade up to 2004 and that the Framingham coronary risk score has actually increased in women 35 to 54 years of age. In the Perth population, despite falling total cholesterol levels, mean body mass index increased significantly in 35- to 64-year-olds between 1980 and 1999, with the greatest increase observed in women 35 to 44 years of age. This is consistent with the increasing prevalence of overweight and obesity shown in national data during our study period, and, furthermore, patients categorized as overweight or obese have been shown to be significantly younger at MI presentation than those of normal weight. These unfavorable trends in obesity and in diabetes prevalence are now estimated to negatively impact on MI incidence and CHD mortality rates, and therefore the adverse trend in ACS incidence in young women warrants further investigation and potential targeting for primary prevention programs.

Study Limitations

There are some limitations associated with administrative datasets, including possible failures in the linkage of hospital records to earlier admissions. However, the audit processes of the WADLS suggest that such failures are rare (0.11%). Our methods did not capture silent MIs or ACS events treated out of hospital. A previous study has shown that a negligible proportion of patients (<1%) with recognized nonfatal MI in Perth are treated completely in primary care, and there is no evidence to suggest that this has increased. The exclusion of ACS patients who were treated in or died in an emergency
department is unlikely to bias our findings because a high proportion of patients who undergo troponin testing are admitted to the hospital, and ≤1% die in the emergency department before admission. Although the WADLS does not capture all hospitalization data for people migrating in and out of state, the small net migration gain in WA over the past decade, primarily resulting from an influx of younger workers, is likely to have limited impact on trends in incidence. Our use of a 10-year look-back period to exclude recurrent ACS events has been used previously and is estimated to exclude most recurrent events. Validation of a national administrative database has shown that inclusion of a small proportion of recurrent events does not bias trends in MI incidence. Identification of incident events from the principal diagnosis field only may exclude some new ACS events. However, increased propensity for recording of secondary diagnoses in the HMDC since the 1990s would have caused an apparent increase in rates if secondary diagnosis fields were used. The change in ICD versions during our study period had limited impact on trends because there were no major changes in coding of ACS and no obvious discontinuity in admission trends for CHD subtypes in our dataset. It is also unlikely that our trend data have been influenced by differences in reimbursement between MI and UA because case-mix funding has not been introduced in WA.

Consistency of coding of MI in administrative data in WA compared with the MONICA definition has been shown in a previous study. Further unpublished validation study in WA using revised epidemiological criteria promulgated by the American Heart Association shows a progressive increase in counts of MI in administrative data relative to decreasing counts when traditional biomarkers alone were included in the American Heart Association classification algorithm. This is consistent with a recent study showing that long-term trends of MI based on traditional biomarkers have declined, whereas those based on troponins have increased. UA has not been fully validated in the WADLS; however, improved management protocols for UA in Australia were published during our study period. These guidelines, along with the recent dissemination of ACS guidelines, could be expected to increase rather than decrease the tendency for other angina to be coded as UA, so that the bias due to changing diagnostic practice for UA is likely to be against the observed downward trend. Furthermore, declines in all incident CHD in our population mirror the declines in incident ACS shown in the current study, indicating that the trends in ACS are not biased by transference between ACS and other variants of CHD. Additionally, hospital admission rates for UA in our population (data not shown) in the period before our study are consistent with comparable trends in UA from the Minnesota Heart Survey for a similar period. Although the uptake in troponin testing from the beginning of our study period is likely to have increased the number of cases diagnosed as MI, there were modest reductions in MI incidence, and declines in UA incidence commenced before the full uptake of troponin testing in suspected MI cases. The overall trends seen in our study therefore conceivably represent real declines in ACS incidence.

Conclusions

This whole-population study has demonstrated a declining incidence of hospitalized ACS from 1996 to 2007. These trends are encouraging and probably reflect primary prevention efforts over several decades. However, the age-standardized results mask age and sex differences, notably in women 35 to 54 years of age, in whom ACS incidence has significantly increased. This warrants further investigation to determine if the impact of troponin testing is selectively greater in this group or whether the recent reversal in the prevalence of cardiovascular risk factors such as diabetes and obesity has contributed to this trend.

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Disclosures

None.

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