CRIME AND JUSTICE

Bulletin

Modelling supply rates of high-strength oxycodone across New South Wales

Deborah Bradford and Laura Rodwell

Aim: The objective of this research was to develop a statistical methodology for identifying areas with aberrantly high supply levels of 80mg oxycodone controlled-release (CR) tablets, a prescription medicine that is currently a target for illicit diversion in Australia. The intention in developing this methodology was to provide assistance to the Pharmaceutical Services unit of the New South Wales Department of Health in monitoring supply and prescribing of high-strength prescription opioids.

Method: Statistical analysis focused on modelling variations across New South Wales (from 2006 to 2009) in wholesale supply rates of 80mg oxycodone CR tablets while controlling for relevant demographic and public health characteristics of each area.

Results: This analysis identified a number of Local Government Areas with supply levels of 80mg oxycodone CR tablets that were significantly higher than that predicted by the statistical model. In contrast to analysis of raw unadjusted supply counts of this medicine, which were highest in areas with large populations, statistical modelling identified mainly regional areas as those with unexpectedly high supply rates of 80mg oxycodone CR tablets.

Conclusion: The current findings highlight the importance of controlling for relevant population level characteristics related to indications for opioid prescribing when evaluating trends in supply of these medicines.

Keywords: illicit diversion, prescription medicines, oxycodone, Pharmaceutical Services, pharmaceutical regulation.

INTRODUCTION

Over the last two decades in Australia there have been substantial increases in the supply and consumption of prescription opioid medications such as morphine and oxycodone. A recent report by the Royal Australian College of Physicians (RACP) estimates that between 1991 and 2007, there was a 10-fold increase in the base supply of oxycodone and a 4-fold increase in the base supply of morphine (RACP, 2009).[1] Similarly, in the last 10 years prescriptions for oxycodone at all strengths have increased markedly, with no indications that rates of prescribing are waning (Leong, Murnion, & Haber, 2009). A proportion of this growth is likely related to legitimate factors such as the increasing prevalence of chronic pain in an ageing population, the introduction of enhanced opioid preparations (e.g., controlled release formulations), and an increased understanding and acceptance of the use of opioids in managing chronic pain. However, there is mounting evidence that some of

this increase also reflects misuse and diversion to the illicit drug market. Indeed, recent indicators of illicit drug use reveal that prescription opioid medications are being used increasingly for non-medical purposes by some groups of injecting drug users (Stafford et al., 2009; National Centre in HIV Epidemiology and Clinical Research, 2007). For example, data from the 2008 wave of the Illicit Drugs Reporting System survey of injecting drug users revealed that 27 per cent of those surveyed in New South Wales (NSW) had used illicitly obtained oxycodone in the previous six months, while 31 per cent had used illicitly obtained morphine (Stafford et al., 2009). These trends are very concerning, due to both the documented increases in health-related harms associated with use/abuse of prescription medicines (Alcohol and other Drugs Council of Australia, 2010; Drug Abuse Warning Network, 2003; 2010; Paulozzi, Budnitz, & Xi, 2006; Roxburgh & Burns, 2009) and the criminal implications associated with the illegal possession, supply and trafficking of these drugs under the *Drug Misuse Trafficking Act* (1985).

In NSW, most prescription opioids are classed as drugs of addiction under Schedule 8 of the Poisons List under the *Poisons and Therapeutic Goods Act* (1966). As part of this classification, there are strict regulations in place concerning the production, supply, and storage of these medicines, as well as guidelines regarding appropriate prescribing practices (RACP, 2009; New South Wales Health, 2009). Despite these safeguards, it is clear that some prescription drugs are being diverted to the illicit market for unauthorised consumption. Diversion of prescription medications to illicit drug markets can occur in a number of ways, including theft, robbery, prescription fraud (see Rodwell, Ringland, & Bradford, 2010 for a review), inappropriate prescribing and prescription shopping (also known as doctor shopping). A growing body of international research indicates that prescription shopping, which involves an individual visiting numerous doctors for the purpose of obtaining multiple prescriptions for a particular drug, is one of the most common methods used to acquire prescription medicines for illicit use (El-Alneed et al., 2009; Inciardi, Surratt, Cicero, & Beard, 2009; Inciardi, Surratt, Kurtz, & Cicero, 2007; National Drug Intelligence Center, 2004; United States Government Accountability Office, 2009). In Australia, there are a number of anecdotal and media reports describing the prescription shopping problem and in some cases, highlighting examples where individuals have sourced large quantities of high-dose prescription opioids using this approach (e.g., Fife-Yeomans, 2008; Four Corners, 2010). However, currently there is a dearth of reliable information on the extent to which prescription shopping and any related inappropriate prescribing contribute to the illicit diversion of prescription opioid medications.

Strategies in NSW to address diversion of prescription medicines

In NSW, one of the primary responsibilities of Pharmaceutical Services of the Clinical Safety, Quality and Governance Branch within the NSW Department of Health is to administer the legislation pertaining to restricted medicines and to ensure that the manufacture, distribution, and prescribing of these substances is consistent with regulations. One of the strategies employed by Pharmaceutical Services to address the diversion and illegitimate use of prescription medications is to search for indications of inappropriate prescribing. This is achieved by analysing Schedule 8 distribution data that is collected routinely as part of existing federal standards on the monitoring of prescription medicines (Australian Government Department of Health and Ageing, 2010; RACP, 2009). Within Pharmaceutical Services, monitoring occurs of the wholesale distribution of Schedule 8 medicines to individual sites of supply (i.e., individual pharmacies or hospitals) across the state (Pharmacy Board of

New South Wales, 2008; RACP 2009). In particular, movements of high-strength prescription opioids such as oxycodone and morphine are targeted in these analyses (Pharmacy Board of New South Wales, 2008). Using this approach, individual sites or geographical areas that are being supplied with Schedule 8 medicines at unusually high levels can be identified and, if necessary, the dispensing records from specific locations can be examined to assess whether prescribing practices of local practitioners are appropriate. At this point, any practitioners identified as prescribing at inappropriate levels can be provided with the necessary counselling and educational interventions to improve their practices. The utility of this strategy in addressing the illicit diversion of prescription medicines is supported by recent research showing that there is a positive relationship between opioid prescribing rates and indicators of diversion and unsanctioned use of these medicines (Dasgupta et al., 2006; Wisniewski, Purdy, & Blondell, 2008). Therefore, examining levels of supply and implementing strategies to address aberrant prescribing practices has the potential to reduce diversion of these medicines to the black market.

It is important to note, however, that rates of supply and prescribing of opioid medications may vary across areas due to entirely legitimate reasons related to the specific characteristics of the local population. Indeed, some areas may have higher prescription rates for opioid pain medications than others because of differences in community-level demographic characteristics (e.g., age, gender distributions and disease incidence). For example, recent population level data in NSW has shown that rates of moderate to severe bodily pain are higher in rural areas compared to urban areas and that there is significant regional variation in self-reported experiences of body pain (Centre for Epidemiology and Research, 2009). Since treatment with opioid pain medications is a legitimate therapeutic intervention for chronic pain it is reasonable that areas with higher rates of bodily pain should have higher levels of supply of these medicines. Similarly, areas with higher cancer incidence rates, which also vary geographically across the state (Tracey, Baker, Chen, Stavrou, & Bishop, 2007), will be more likely to have higher levels of prescribing and supply of opioid pain medications than areas with lower cancer incidence rates. Clearly, these types of factors play an important role in rates of prescribing for pain medications and are critical to account for in evaluating trends in supply across areas. The development of a method that could account for important demographic and public health variables in identifying high level opioid distribution areas therefore, has the potential to be beneficial to agencies like Pharmaceutical Services that are tasked with monitoring prescribing on a state-wide basis.

THE CURRENT STUDY

The objective of the current study is to develop, on a preliminary basis, a systematic methodology for identifying locations with aberrantly high supply levels of prescription opioids, which may assist Pharmaceutical Services in their monitoring and investigation practices. This aim of this methodology is to make the process of identifying areas with high supply rates of prescription medicines more efficient, while allowing Pharmaceutical Services to take account of a broad range of factors that may legitimately influence prescribing rates in their investigations.

This will be achieved by:

1. Statistically modelling variations in wholesale supply rates of high-dose prescription opioids to Local Government Areas (LGAs) across NSW, whilst accounting for relevant population and public health characteristics of the population resident in each area.

2. Comparing regions identified by statistical modelling as high supply areas with those identified as high on the basis of raw unadjusted supply counts.

METHOD

This study draws upon administrative data from the National Drug Control System (NDS). This system records movements of Schedule 8 medicines between licensed wholesalers and establishments (e.g., pharmacies, hospitals and other health premises) that are authorised to sell and/or administer these medicines.

BOCSAR was provided with NDS[2] data for January 2001 to December 2009 pertaining to movements of Schedule 8 medicines supplied to establishments located in NSW. These data included information on the quantity, formulation, and strength of the drug involved in each movement, as well as detailed information on the establishment involved in each transaction. Each recorded movement corresponded to a single transaction record (e.g., a sale or return of a specific drug formulation).

For the purposes of the study, establishments were restricted to pharmacies. Data on movements to/from pharmacies were aggregated at the LGA level, linking the suburb and postcode variables in the NDS data to the 2006 LGA concordance data. This allowed for data coded at the suburb/postcode level to be converted to an LGA level. All variables used in statistical analyses were estimated at the LGA level.

Additional data sources used in analyses included population distribution data from 2003 to 2009 obtained from the Australian Bureau of Statistics as well as data relating to other demographic and morbidity variables obtained from the Social Health Atlas of Australia 2010 (maintained by the Public Health Information Development Unit at the University of Adelaide; PHIDU, 2010).

DEPENDENT VARIABLE

The dependent variable was the count of the net number of 80mg oxycodone controlled-release (CR) tablets supplied to an LGA in a calendar year (the total number of tablets supplied to pharmacies in an LGA minus those returned from that same LGA within each year). This oxycodone preparation was selected because it is a high-dose opioid and is one of the key drugs targeted in Pharmaceutical Services' investigations of inappropriate prescribing and supply of Schedule 8 medicines (Pharmacy Board of New South Wales, 2008).

EXPLANATORY VARIABLES

In order to account for legitimate variation in the net supply of 80mg oxycodone CR tablets, a number of explanatory variables likely to be associated with opioid prescribing practices or area level variations in supply and demand of prescription medicines were tested in the model. These variables are listed below.[3] Unless otherwise specified, the variables are time dependent, in that their values were allowed to vary from year to year.

Base amount of equivalent morphine (100mg+): The aggregated net total (in grams) of base morphine in tablets and capsules of 100mg or greater strength supplied to each LGA was included to adjust for any area-level variations in prescribing associated with pain management.[4]

Base amount of oxycodone tablets and capsules of less than 80mg strength: The aggregated net total (in grams) of base oxycodone in tablets and capsules with a strength lower than 80mg supplied to each LGA was also included to account for any area-level variations in prescribing for legitimate pain management.

Proportion of persons aged 55 and over: For each LGA, this variable was calculated as the proportion of persons aged 15 and over who were aged 55 and over. LGAs were grouped into one of three categories based on tertiles (17.0% to 30.6%; 30.7% to 37.7%; 37.8% to 51.8%). This was included to account for the positive association between age and bodily pain, particularly among those aged over 55 (Centre for Epidemiology and Research, 2009).

Adjacent pharmacy count: The count of the number of pharmacies in adjacent LGAs was included to account for the possibility that individuals with limited pharmacy access in their own LGA would obtain their medications in an adjacent LGA.[5]

This variable grouped LGAs into one of four categories based on quartiles (0 to 14; 15 to 37; 38 to 92; 93+).

Standardised ratio for deaths from cancers (fixed variable): To account for geographical variations in legitimate opioid prescribing associated with cancer-related pain, the standardised ratio (SR) of deaths from cancers for persons aged 15 to 64 for each LGA (aggregated across 2003 to 2007) was included in the analyses. This measure was based on area of usual residence and was selected as a proxy for LGA level data on cancer incidence, which due to time constraints, was not available at the time of study.

Proportion of persons in the population with a profound or severe disability (fixed variable): The proportion of persons in an LGA with a profound or severe disability living in the community (estimated in 2006). This measure was included to account for differences in legitimate opioid prescribing rates associated with disability-related pain.

OFFSET VARIABLE

To adjust for the difference in population size across LGAs, an offset variable adjusting for the number of persons aged 15 years and over was specified in the model. This value corresponded to the natural log of the number of persons aged 15 or older.

ANALYSIS

A generalised estimating equations (GEE) approach was used to model the data. This methodology accounts for the repeated measures nature of the data, in that net supply of 80mg oxycodone CR tablets was measured across multiple years. The dependent variable (wholesale supply of 80mg oxycodone CR tablets) was measured at the LGA level, with the offset measure of the number of persons aged 15 and over in each LGA included to adjust for differences in population size.

Preliminary investigation of the data indicated that there was a notably higher zero count of supply of 80mg oxycodone CR tablets recorded from 2001 to 2005 than from 2006 onwards. Because we could not rule out the possibility that this discrepancy was related to the change in data monitoring systems from DRUMS to NDS in 2004, analyses were restricted to transactions involving 80mg oxycodone CR tablets in the years 2006 to 2009.

Statistical modelling was conducted in SPSS version 19. All variables were initially entered into the model, with non-significant variables removed. The form of the working correlation matrix in the GEE model was initially selected by assessing the correlations between the counts of 80mg oxycodone CR tablets in each year. The fit of the model for the structure chosen based on the correlation was then formally

compared to other structures using the quasi-likelihood under the independence model criterion (QIC: Pan, 2001).

Pearson residuals were generated and plotted against each year to identify the outlying observations. To ensure confidentiality, the LGAs were randomly allocated a number to present in the residual plots displayed in the next section.

RESULTS

LOCAL GOVERNMENT AREAS

Of the 152 LGAs within NSW, four LGAs had no movements of Schedule 8 medicines to pharmacies. Population data for two of these LGAs were incorporated into another adjacent LGA with a high level of supply of 80mg oxycodone CR tablets.[6] The remaining two LGAs with no data on movements of Schedule 8 medicines had small populations and were not located next to other LGAs with sufficiently high levels of supply of 80mg oxycodone CR tablets to warrant combining the data. These two remaining LGAs were therefore excluded from further analysis. A fifth LGA that had either zero counts or a net movement of returns rather than sales of 80mg oxycodone CR tablets over the years of study was removed from further analysis. Two other LGAs were also excluded from analysis because there were no values available for one of the explanatory variables (deaths from cancers) and there were very low levels of supply of 80mg oxycodone CR tablets recorded in these areas. In total, supply rates of 80mg oxycodone CR tablets for 145 LGAs were included in the final analysis.

The count of pharmacies across LGAs ranged from 1 to 113 from 2006 to 2009, with a median of 7 per LGA.

MODEL DEVELOPMENT

Specification of the distribution

Table 1 shows the mean number of 80mg oxycodone CR tablets supplied to pharmacies per LGA and Table 2 shows the mean number of tablets distributed per day per 1,000 persons from 2006 to 2009. In both tables the yearly values are averaged across LGAs state-wide. As shown in the tables, both the average number of tablets per LGA supplied to pharmacies and the average number of tablets supplied per population (per 1,000 persons per day) increased steadily over time. In addition, the values for the standard deviation of the mean displayed in Table 1 are much larger than the mean values across all years of analysis. This indicates that a negative binomial approach is a suitable method for modelling the data.

Figure 1 presents box plots showing the raw counts of 80mg oxycodone CR tablets supplied to each LGA from 2006 to
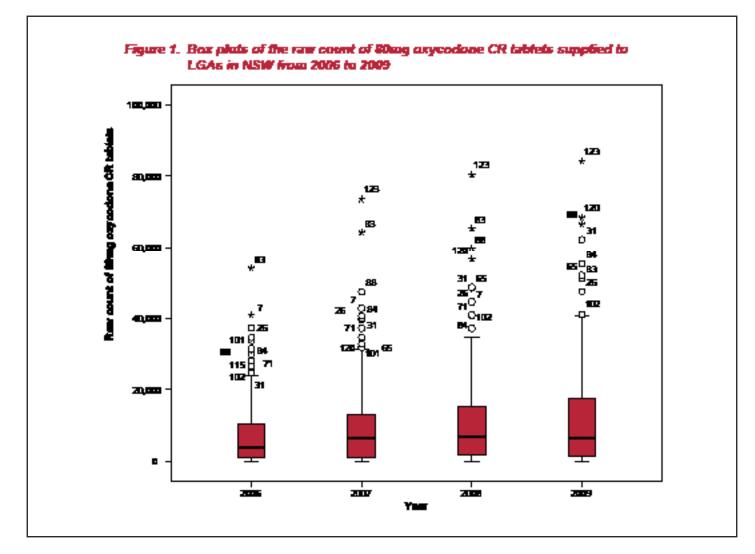
Table 1. Descriptive statistics on the number of 80mg oxycodone CR tablets distributed (per LGA) in NSW from 2006 to 2009

Year	Mean	Standard deviation	Median	Range
2006	7,845.66	9,695.36	3,920	0 – 54,220
2007	9,986.28	12,625.20	6,460	0 – 73,560
2008	11,738.76	14,481.16	6,780	0 – 80,340
2009	12,647.45	15,748.98	6,960	0 – 84,140

Table 2. Average number of 80mg oxycodone CR tablets distributed per 1,000 persons per day (per LGA) across NSW from 2006 to 2009

Year	Mean	Range
2006	0.70	0 – 4.38
2007	0.82	0 – 5.32
2008	1.00	0 – 4.12
2009	1.04	0 – 5.10

2009. In the box-plot, the lower border of the box represents the 25th percentile point, the upper border of the box represents the 75th percentile point and the line in the box corresponds to the median point of the data. The space between the box and the boundaries of the upper and lower whiskers correspond approximately to the upper and lower 25% of the data. The values that are shown beyond the whiskers of the box plot represent extreme values that deviate significantly from the rest of the distribution. The most deviant values are indicated by asterisks. In Figure 1, each number in the box plot corresponds to an individual LGA and the extreme values hovering above the whiskers of the box represent those areas with the highest level of supply of 80mg oxycodone CR tablets. In Figure 1, these extreme values correspond to urban LGAs with large populations. This is not surprising because areas with large populations will by virtue of their size have higher levels of supply of prescription medicines. However, this finding does highlight the importance of adjusting for differences in population size (using the offset variable) in measuring area-level differences in supply of oxycodone.

Figure 1. Box plots of the raw count of 80mg oxycodone CR tablets supplied to LGAs in NSW from 2006 to 2009

Specification of the working correlation matrix

Table 3 presents the correlation between the total numbers of 80mg oxycodone CR tablets supplied in NSW (aggregated across LGAs) from 2006 to 2009. As shown in the table, the correlation is strongest between successive years and reduces as the time between years increases. This reflects the fact that the count of 80mg oxycodone CR tablets increased steadily across the years of study. These findings suggest an initial specification of an AR(1) working correlation matrix is appropriate in the GEE model.

MULTIVARIABLE MODEL

The final multivariable model was specified as a negative binomial GEE model, with the offset and an AR(1) working correlation matrix with robust variance specification. Further information on the selection of this methodology is provided in the Appendix. The results are presented in Table 4.[7]

Consistent with the observed yearly increase in the raw count of 80mg oxycodone CR tablets presented in Table 1, results displayed in Table 4 show an annual increase of 13.5 per cent in the number of 80mg oxycodone CR tablets supplied to pharmacies. Supply rates of 80mg oxycodone CR tablets also increased with: the proportion of persons in an LGA with a profound or severe disability; the equivalent base of morphine supplied to an LGA; and the incidence of cancer related deaths. LGAs with a high count of adjacent pharmacies (over 14) had lower supply rates of 80mg oxycodone CR tablets than LGAs with a low count of pharmacies in adjacent LGAs (14 or fewer). This suggests that LGAs with a small number of surrounding pharmacies are more likely to have a higher level of supply

Table 3.   Correlation matrix of the count of 80mg oxycodone CR tablets supplied from 2006 to 2009

Year	2006	2007	2008	2009
2006	1.000			
2007	0.948	1.000		
2008	0.906	0.976	1.000	
2009	0.864	0.937	0.972	1.000

of 80mg oxycodone CR tablets. With the exception of the equivalent morphine base variable (which had a significant quadratic term) each of the continuous variables presented a linear trend in the model.
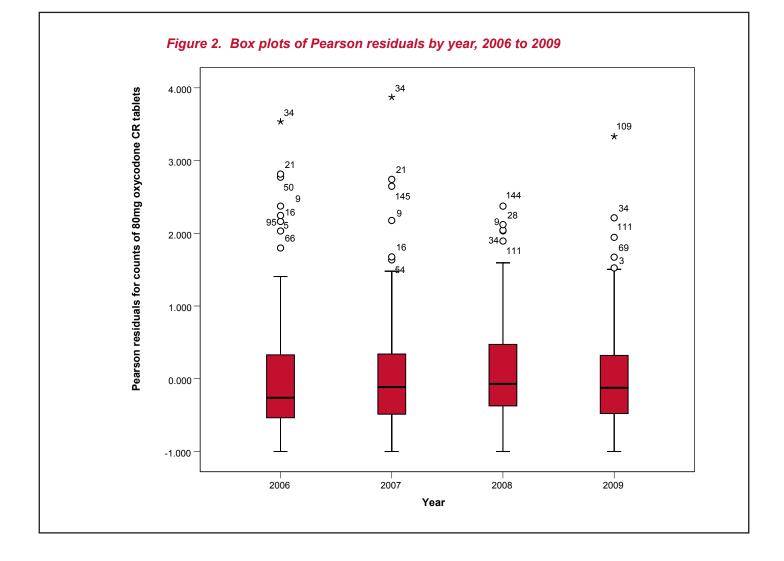
Using the model specified above, Pearson residual values were generated to assess the discrepancy between the observed counts of 80mg oxycodone CR tablets and those predicted by the model for each LGA. These residuals are displayed in a box plot in Figure 2, with each number presented in the box plot corresponding to a unique LGA. Across all years of study, there were LGAs identified with an observed level of supply of 80mg oxycodone CR tablets that was higher than that predicted by the model. For example, in 2009 there was one LGA (109) with a particularly high outlying value and, another four LGAs (34, 111, 69, and 3) were located beyond the whiskers of the box plot. In contrast to Figure 1, where these outlying values corresponded to urban LGAs with high populations, the LGAs with outlying values in Figure 2 were mainly in regional areas. None of the high population areas identified as outliers in the raw count analysis presented in Figure 1 appeared as extreme values in Figure 2.

Table 4. Incident rate ratios with 95% confidence intervals and associated p-values

Variable	IRR	95 % Confidence Interval	p-value
Year	1.135	(1.087, 1.185)	<.001
Severe or profound disability	1.238	(1.104, 1.388)	<.001
Adjacent pharmacy count			
0 to 14 (ref)[a]			
15 to 37	0.644	(0.500, 0.829)	.001
38 to 92	0.651	(0.497, 0.852)	.002
93+	0.566	(0.425, 0.754)	<.001
Equivalent morphine (grams)	1.001	(1.000, 1.001)	<.001
Equivalent morphine (squared)	1.000[b]	(1.000, 1.000)	.001
Deaths from cancer (SR)	1.006	(1.002, 1.010)	.008

[a] Wald test for joint significance p < .001

[b] Actual point estimate value = -0.000000158

Figure 2. Box plots of Pearson residuals by year, 2006 to 2009

As an example, in LGA 109 the number of 80mg oxycodone CR tablets supplied more than doubled from 2,700 in 2008 to 6,220 in 2009. While some of this increase is likely related to the fact that supply of 80mg oxycodone CR tablets increased overall from year to year (as shown in Table 1), the fact that this escalating yearly supply trend is accounted for in the model suggests that the growth observed in LGA 109 is greater in magnitude than the general increase in supply of 80mg oxycodone CR tablets from year to year. Another factor that may have influenced the level of supply of 80mg oxycodone CR tablets to LGA 109 was that the number of pharmacies in the LGAs adjacent to LGA 109 decreased from 23 pharmacies in 2008 to 20 in 2009.

DISCUSSION

The primary objective of the current study was to develop a systematic methodology for identifying areas with unusually high supply levels of 80mg oxycodone CR tablets, a high-dose prescription opioid that is currently a target for illicit diversion.

The intention in developing this approach was to assist the NSW Department of Health Pharmaceutical Services unit in their on-going monitoring and investigation of prescribing of restricted medicines. The results of this analysis revealed that statistically controlling for demographic, morbidity and mortality factors associated with legitimate medical use of 80mg oxycodone CR tablets identified a number of areas across NSW with supply levels that were significantly above the rest of the state. In contrast to the analysis of raw unadjusted supply counts of 80mg oxycodone CR tablets, which indicated that supply was highest in urban areas with large populations, the final statistical model that took account of population level differences identified mainly regional areas as those with the highest level of supply of this medicine.

While more in-depth analysis by investigators from Pharmaceutical Services is necessary to determine whether any inappropriate prescribing and illicit diversion of opioids is occurring in these areas, these findings demonstrate the importance of controlling for relevant population characteristics when evaluating trends in supply of these medicines. Indeed,

an important advantage of this approach is that it provides more accurate indications of aberrantly high supply levels than simple analyses examining the raw volume of tablets supplied to a particular area. In addition, the application of this methodology by Pharmaceutical Services has the potential to reduce both the time and resources currently required for investigators to monitor rates of supply across the state. By utilising this approach and automating the process of identifying areas with high distribution rates, the efficiency of the initial search for aberrant supply areas could be enhanced. As a result, investigators could have the opportunity to dedicate more time to examining local prescribing practices and implementing any necessary counselling or educational interventions on a targeted basis.

While this research provides an important first step in developing a more systematic approach to tracking supply of high-dose prescription opioids across the state, it also has some limitations. Firstly, this research does not distinguish between licit and illicit use of prescription medicines, nor does it account for the prevalence of drug misuse or illicit drug use within geographic areas. Indeed, this methodology focuses solely on identifying areas that have a higher level of wholesale supply of 80mg oxycodone CR tablets than that predicted from certain demographic, morbidity and mortality characteristics of each LGA population. Although there may be inappropriate prescribing and illicit diversion occurring in these areas, the identified areas may have high levels of supply of this medicine for legitimate medical reasons. For example, areas that have large hospitals or pain treatment services might require a high level of supply of prescription opioid medications irrespective of the LGA population characteristics accounted for in the current methodology. Another limitation is that the influence of prescriber level factors (e.g., age, speciality, number of medical practitioners) is not considered in estimating deviations in supply rates across LGAs. While the density of medical professionals within a given area is likely to be related to the LGA population size, it is possible that there are some practitioner level characteristics that could be influencing the current findings. In addition, this approach does not account for whether prescribing and dispensing occurs within the same LGA. Therefore, it is possible that there may be some LGAs, particularly those with pharmacies close to other LGA borders, which may show inflated supply rates because pharmacies are dispensing medicines to patients receiving their prescriptions from practitioners in another area. However, the extent to which this may be influencing the observed deviations in wholesale supply rates cannot be estimated using the current data.

Another limitation of the data used in the current study is that it focused on aggregate supply at an LGA level. This level of analysis was not sufficient to enable inferences to be made about any abnormalities in local pharmacy dispensing or individual prescribing patterns. In addition, it is possible that some larger areas (with a high number of pharmacies) which may have practitioners prescribing opioids in an inappropriate manner would not be identified when supply rates are analysed at an area level. This limitation highlights the need to develop and implement improved monitoring systems of prescribing and dispensing in NSW. Indeed, the introduction of comprehensive data monitoring systems, such as those that provide real-time electronic tracking of prescriptions, as recently introduced in Tasmania, may significantly reduce diversion and any related inappropriate prescribing of prescription medicines more than monitoring of wholesale supply rates.

Finally, this research is a preliminary exploration of whether a systematic tool for identifying areas with aberrant supply rates of high-dose prescription opioids could be of assistance to regulatory bodies like Pharmaceutical Services. While the current findings have demonstrated the importance of controlling for relevant demographic and public health characteristics of the LGA population in monitoring supply levels of 80mg oxycodone CR tablets, it is possible that the measures employed in statistical modelling could be improved upon by using other measures more closely related to variations in prescribing rates of this medicine. Further research investigating the optimal combination of factors associated with supply of high-dose prescription opioids to include in this methodology is needed to examine this issue in greater depth. In addition, future research exploring the application of this methodology to other drugs targeted for unauthorised use (e.g., benzodiazepines) would be of benefit in addressing the growing problems associated with the illicit diversion of prescription medicines.

ACKNOWLEDGMENTS

NOTES

1. The total amount of oxycodone/morphine supplied (in grams) across all medicine forms and dosages.

2. Up until mid-2004 the data monitoring system used to record movements of Schedule 8 medicines was called DRUMS. In 2004, the NDS database was initiated to replace the DRUMS database.

3. Survey data on self-reported experiences of bodily pain was assessed for inclusion in analyses; but, there were insufficient survey observations at the LGA level to be included in statistical modelling.

4. Base quantity of morphine tablets/capsules of 100mg strength or greater is approximately equivalent in its analgesic effects to high-strength oxycodone (MIMS Online, 2010; RACP, 2009).

5. Data on interstate pharmacies was not available. This is likely to result in an underestimate in adjacent pharmacy counts for LGAs bordering other states.

6. This approach was selected in order to make a conservative estimate of 80mg oxycodone CR tablet supply in these areas.

7. From the original variables outlined, two were not statistically significant in the final model. The proportion of persons aged 55 plus (p=.627) and the base total of oxycodone tablets and capsules of less than 80mg strength (p=.806).

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APPENDIX

Table A1. Quasi-likelihood under the independence model criterion (QIC) values for different working correlation matrix specifications

Specification	QIC
AR(1)	681.04
Independent	690.28
Exchangeable	684.89
Unstructured	687.30

Note. Smaller QIC values indicate a better model.

The quasi-likelihood under the independence model criterion (QIC) for GEE was first proposed by Pan (2001) and is an extension of the Akaike Information Criterion (AIC) for model comparison and selection. The use of the QIC in GEE model selection is necessary due to the GEE having different asymptotic properties from those of the maximum likelihood estimator (Pan, 2001). The QIC enables the comparison of non-nested GEE models, including the comparison of different working correlation structures.

The comparison of the QIC with those of other working correlation matrix structures indicated that AR(1) was the most appropriate specification for this model.

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