

# Healthcare costs of investigations for stillbirth from a population-based study in Australia

Louisa G. Gordon  <sup>1,2,3,8</sup> PhD, Senior Research Fellow

Thomas M. Elliott  <sup>1</sup> MHealthEcon, Health Economist

Tania Marsden <sup>4,5</sup> MMedSci, Pathologist

David A. Ellwood <sup>5,6</sup> MBBS, Head of School

T. Yee Khong <sup>5,7</sup> MBBS, Pathologist

Jessica Sexton <sup>4,5</sup> MPH, PhD Student

Vicki Flenady <sup>4,5</sup> PhD, Director

<sup>1</sup>QIMR Berghofer Medical Research Institute, Population Health Department, Locked Bag 2000, Royal Brisbane Hospital, Herston, Qld, Australia. Email: thomas.elliott@qimrberghofer.edu.au

<sup>2</sup>School of Nursing and Institute of Health and Biomedical Innovation, Queensland University of Technology, Kelvin Grove, Qld, Australia.

<sup>3</sup>The University of Queensland, School of Public Health, Herston, Qld, Australia.

<sup>4</sup>Mater Research Institute, The University of Queensland, Brisbane, Qld, Australia.

Email: t.marsden@uq.net.au; jessica.sexton@uq.edu.au; vicki.flenady@mater.uq.edu.au

<sup>5</sup>National Health and Medical Research Council (NHMRC) Centre for Research Excellence in Stillbirths, South Brisbane, Qld, Australia.

<sup>6</sup>Griffith University, School of Medicine, Gold Coast, Qld, Australia. Email: d.ellwood@griffith.edu.au

<sup>7</sup>Women's and Children's Hospital, Adelaide, SA, Australia. Email: Yee.Khong@adelaide.edu.au

<sup>8</sup>Corresponding author. Email: louisa.gordon@qimrberghofer.edu.au

## Abstract.

**Objective.** Stillbirth investigations incur healthcare costs, but these investigations are necessary to provide information that will help reduce the risk of a recurrent stillbirth, as well as advice regarding family planning and future pregnancies. The aims of this study were to determine the healthcare costs of investigations for stillbirths, identify drivers and assess cost differences between explained and unexplained stillbirths.

**Methods.** Data from 697 stillbirths were extracted from the Stillbirth Causes Study covering the period 2013–18. The dataset comprised all investigations related to stillbirth on the mother, baby and placenta. Unit costs applied were sourced from the Australian Medicare Benefits Schedule, local hospital estimates and published literature. Multivariable regression analyses were used to assess key factors in cost estimates.

**Results.** In all, 200 (28.7%) stillbirths were unexplained and 76.8% of these had between five and eight core investigations. Unexplained stillbirths were twice as likely to have eight core investigations as explained stillbirths (16.5% vs 7.7%). The estimated aggregated cost of stillbirth investigations for 697 stillbirths was A\$2.13 million (mean A\$3060, median A\$4246). The main cost drivers were autopsies or cytogenetic screening. Mean costs were similar when stillbirths had known or unknown causes and by reason for stillbirth among cases with definable causes.

**Conclusion.** Investigations for stillbirth in Australia cost approximately A\$4200 per stillbirth on average and are critical for managing future pregnancies and preventing more stillbirths. These findings improve our understanding of the costs that may be averted if stillbirths can be prevented through primary prevention initiatives.

**What is known about the topic?** Approximately 2000 stillbirths occur each year in Australia, and this trend has not changed for several decades. Stillbirth investigations incur healthcare costs, but these investigations are necessary to provide information to help reduce the risk of a recurrent stillbirth and advice regarding family planning and future pregnancies. Recommendations for the core set of stillbirth investigations have recently been agreed upon by consensus.

**What does this paper add?** The costs of stillbirth investigations are unknown in Australia. The assessment of these costs is challenging because not all investigations involved in stillbirths are recorded within formal administrative systems because a stillborn baby is not formally recognised as a patient. The present population-based analysis of 697 stillbirths in

Australia estimated that, on average, A\$4200 was spent on investigations for each stillbirth, with key drivers being autopsies and cytogenetic screening. These costs are typical, with most cases having between five and eight of the core eight recommended investigations.

**What are the implications for practitioners?** There are cost implications for stillbirth investigations, and this analysis gives a true account of current practice in Australia. Together with the high downstream economic costs of stillbirths, the cost burden of stillbirth investigations is high but ultimately avoidable when practitioners adhere to the core investigations, build knowledge around preventable risk factors and use this information to reduce the number of stillbirths.

**Keywords:** cost analysis, fetal autopsy, health economics, high-risk pregnancies, investigations, prevention initiatives, stillbirths, unexplained stillbirth.

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## Introduction

Each year there are approximately 2100 stillbirths in Australia, equating to 6.8 per 1000 pregnancies or six stillbirths per day.<sup>1</sup> This rate is similar to that in other developed countries, and has stabilised over two decades despite significant parallel improvements in childhood mortality rates.<sup>2</sup> Stillbirths are a deeply emotional and painful experiences for parents, who often experience long-term psychological effects. Although the causes of most stillbirths are known, approximately 20% of all stillbirths are unexplained despite intensive testing.<sup>1</sup> An unexplained stillbirth creates problems in terms of inadequate closure for parents, planning subsequent pregnancies and the psychological well-being of parents. Yet, there is still a lack of attention and research in monitoring and understanding why these events occur to enable effective prevention initiatives.<sup>3</sup>

In Australia, stillbirths are classified according to the Perinatal Society of Australia and New Zealand (PSANZ) Perinatal Death Classification (PDC) Clinical Practice Guideline.<sup>4</sup> According to the most recent national report based on five states and territories (representing 60% of all perinatal deaths), the most common cause of deaths was congenital anomalies (31%), followed by spontaneous preterm birth (14%) and unexplained antepartum death (12%).<sup>5</sup> There may also be multiple causes of a stillbirth, making single classifications difficult. Performing more investigations to find the cause of an unexplained stillbirth may or may not result in a definitive diagnosis, but it will increase healthcare costs. Although there is no consensus on the recommended stillbirth investigation protocols across countries, there appears to be general agreement on a core set of investigations in Australia, and these have culminated in new clinical guidelines.<sup>4</sup> If necessary, further investigations are optional depending on the results of the core investigations.

Several studies have described the costs of stillbirths in various countries.<sup>6–10</sup> Compared with live births, additional healthcare costs of US\$2000–5000 have been reported.<sup>6–10</sup> Although additional investigations will increase direct healthcare costs in the immediate term, they are necessary to provide: (1) information that will help reduce the risk of recurrent stillbirths; and (2) advice with family planning and future pregnancies. Approximately 52% of mothers who have had a stillbirth are pregnant again within 12 months.<sup>6</sup> Fully

understanding the scope and value of stillbirth investigations may avoid unnecessary costs to the health system associated with autopsy costs, bereavement counselling and future high-risk pregnancies.

In 2019, the PSANZ recommended eight core investigations (unless the cause of death was unequivocally determined antenatally).<sup>4</sup> Optional additional investigations could be undertaken subject to information revealed from the core investigations. The core investigations are: (1) comprehensive maternal (medical, social and family) and pregnancy history; (2) Kleihauer–Betke test/flow cytometry for fetal-to-maternal haemorrhage; (3) external examination of the baby performed by the attending clinician; (4) clinical photographs of the baby; (5) autopsy (full or limited); (6) detailed macroscopic examination of the placenta and cord; (7) placental histopathology; and (8) cytogenetic screening (chromosomal microarray or karyotype).

The aim of the present study was to evaluate the costs of stillbirth investigations in Australia using data from the Stillbirth Causes Study.<sup>11</sup> With a focus on the core PSANZ investigations, we determined the costs of actual tests and investigations on a large cohort, assessed differences among explained and unexplained stillbirths and identified factors that could explain any cost differences.

This study was approved by the Mater Health Services Human Research Ethics Committee and all collaborating clinical sites (HREC/1745M).

## Methods

The cost analysis is based on a cohort of 697 prospective stillbirth cases entered into a purpose-built Stillbirth Causes Study database. Data were extracted from the database covering the period 2013–18. The registry was newly established in 2013 and included consecutive cases of stillbirth ( $\geq 20$  weeks gestation or  $\geq 400$  g birthweight excluding terminations of pregnancy) from 18 maternity hospitals in Australia. Although the PSANZ 2019 stillbirth investigation guidelines were ratified after the study cases were entered, we were interested in current testing levels against the new guidelines to indicate baseline adherence. Prior to 2019, earlier PSANZ guidelines<sup>12–14</sup> recommended more comprehensive testing. The dataset provided detailed records on stillbirths, the mother's

sociodemographic profile (e.g. age, marital status, occupation, education, ethnicity, country of birth, history of smoking and drug use), obstetric history, body mass index (BMI), previous pregnancies, maternal outcome and the investigations undertaken for determining the cause of the stillbirth. Details on the baby included sex, body measurements and the results of the investigations.

The dataset comprised all investigations related to stillbirth on the mother, baby and placenta. Hospitals were required to submit data into an online database for the National Perinatal Death Clinical Audit Tool Confidential Report and Investigations supplement. Due to the design of the data entry (mandatory fields), most variables were very complete. If no data were recorded for an investigation, it was presumed that it was not performed. The PSANZ-PDC system was used to classify the cause of death for all stillbirths. Where the cause of death classification was missing (<4%), the study coordinating site classified the cause of death using all available study data, including the clinical database, autopsy reports and/or pathology reports. Any missing data are the result of either clerical error or the absence of final reports at the time the case was entered into the database.

The investigations recorded in the dataset and included in the analysis were categorised according to the PSANZ guidelines as:

- core investigations (maternal and pregnancy history, Kleihauer–Betke test, external examination of the baby, clinical photographs, autopsy, placental examination, placental histopathology and cytogenetic screening)
- selective investigations (based on findings of core investigations: ultrasound, amniocentesis, vaginal swabs, blood tests (full blood count, viruses, bacteria, blood group, renal/liver and bile acids/thyroid tests, HbA1c, drug screen), thrombophilia tests; post-birth investigations on the baby: surface swabs, cord blood samples, blood for chromosomal analysis, Guthrie test, placental microbiological cultures)
- alternative investigations (when permission for a full autopsy was not obtained: external baby examination, babygram, magnetic resonance imaging, postmortem ultrasound, needle biopsy and laparoscopy).

The unit costs applied to each investigation were sourced from the Australian Medicare Benefits Schedule (MBS) reimbursement codes, local hospital estimates and published literature (Appendix 1). Not all investigations involved in stillbirths are recorded within formal administrative systems because a stillborn baby is not formally recognised as a patient; therefore, it was necessary to rely on pathology advice. The cost of autopsy is highly variable depending on whether a full or limited autopsy is performed and the different set of investigations used. We applied a simple average of A\$3441.15 of the highest and lowest cost examples as a reasonable estimate of the mean autopsy cost. Specific details are provided in Appendix 1.

### Statistical analysis

Descriptive analyses were performed on the mother's sociodemographic and clinical data using frequencies and

percentages for categorical data and the mean  $\pm$  s.d. for continuous data. Costs for core, selective and alternative investigations, as well as total costs (combined costs), were summarised as the mean  $\pm$  s.d., median value and range (minimum–maximum values). Sociodemographic and clinical data were stratified by 'explained' versus 'unexplained' stillbirths, and the significance of differences was tested using Pearson's Chi-squared tests or Student's *t*-tests for categorical or continuous data respectively.<sup>15</sup> Total costs had a distinct bimodal distribution where cases with or without an autopsy had high or low costs respectively. Therefore, ordinary least-squares regressions were performed for the autopsy and non-autopsy groups separately. Sociodemographic and treatment variables were assessed in bivariate models and were excluded from multivariable regression based on their statistical significance, which was set at two-tailed  $P < 0.05$ . Model goodness of fit was based on the adjusted  $R^2$ . All analyses were performed in Stata SE version 15 (StataCorp, College Station, TX, USA).

### Results

The mean age of the mothers was  $30.8 \pm 6.2$  years, and two-thirds were Australian born (Table 1). Over half the mothers were married (58%) or in a de facto relationship (28%); 48% resided in Queensland. Women identifying as Caucasian made up 63% of the sample, 8% identified as Aboriginal and Torres Strait Islander, 6% identified as South Asian and 18% were a mix of other ethnicities. Among all women, 11% had had more than four previous pregnancies, and the mean BMI was  $26.3 \text{ kg m}^{-2}$  (with a BMI of  $25\text{--}29.9 \text{ kg m}^{-2}$  considered overweight). The most common pre-existing medical conditions reported were asthma, a mental health disorder, fertility treatment, an endocrine disorder and hypertension. A small number of women reported smoking (14%) or using alcohol (3%) or drugs (3%) during pregnancy. Queensland mothers, younger age and those born outside Australia had higher frequencies of unexplained stillbirths (Table 1).

Of all stillbirths, 200 (28.7%) were unexplained. Overall, 76.8% of cases had between five and eight core investigations. Cases of unexplained stillbirths had higher frequencies of Kleihauer–Betke testing, clinical photographs and cytogenetic screening (Table 2). Unexplained stillbirths were twice as likely to have all core investigations as explained stillbirths (16.5% vs 7.7%; Table 2). Various causes of stillbirths were recorded, including hypoxic peripartum death (1.8%) and congenital abnormalities (17.5%; Table 2).

The total cost of stillbirth investigations for 697 stillbirths was A\$2.13 million (mean \$3060, median \$4246, range \$35–5639). Core investigations accounted for 86% of total costs (A\$1.84 million; mean \$2645, median \$3941, range \$0–5639; Fig. 1). All other non-core investigations cost A\$28 8916 (13.5% of total costs). The main cost drivers were for autopsies and cytogenetic screening.

The unadjusted results revealed mean costs for the autopsy and non-autopsy groups of  $\$4840 \pm 342$  and  $\$1067 \pm 383$  respectively. After adjustment for cytogenetic screening, Kleihauer–Betke tests, photographs and the number of investigations performed, the costs in the autopsy and non-autopsy groups were  $\$3765$  (adjusted  $R^2 = 0.811$ ;  $n = 363$ ) and  $\$247$

**Table 1. Sociodemographic and medical characteristics of mothers by explained and unexplained stillbirths ( $n = 697$ )**

Unless indicated otherwise, data are given as n (%). ACT, Australian Capital Territory; NSW, New South Wales; NT, Northern Territory; Tas., Tasmania

	Explained ( $n = 497$ )	Unexplained ( $n = 200$ )	Total ( $n = 697$ )	<i>P</i> -value
Mean ( $\pm$ s.d.) age (years)	31.1 $\pm$ 6.4	30.0 $\pm$ 5.6	30.8 $\pm$ 6.2	0.030
State				
NSW	112 (22.5)	33 (16.5)	145 (20.8)	
Victoria	88 (17.7)	25 (12.5)	113 (16.2)	
Queensland	224 (45.1)	110 (55.0)	334 (47.9)	0.000
South Australia	31 (6.2)	2 (1.0)	33 (4.7)	
Tas./NT/ACT	35 (7.0)	29 (14.5)	64 (9.2)	
Missing	7 (1.4)	1 (0.5)	8 (1.1)	
Marital status				
Married	289 (58.2)	118 (59.0)	407 (58.4)	
De facto	143 (28.8)	52 (26.0)	195 (28.0)	0.854
Sole parent	36 (7.2)	16 (8.0)	52 (7.5)	
Divorced or separated	9 (1.8)	3 (1.5)	12 (1.7)	
Missing	20 (4.0)	11 (5.5)	31 (4.4)	
Country of birth				
Australia	347 (69.8)	125 (62.5)	472 (67.7)	
India	23 (4.6)	7 (3.5)	30 (4.3)	0.052
China	9 (1.8)	3 (1.5)	12 (1.7)	
New Zealand	8 (1.6)	9 (4.5)	17 (2.4)	
All other countries	100 (20.1)	53 (26.5)	153 (22.0)	
Missing	10 (2.0)	3 (1.5)	13 (1.8)	
Ethnicity				
Caucasian	306 (61.8)	134 (67.0)	440 (63.1)	
Aboriginal and Torres Strait Islander	40 (8.1)	14 (7.0)	54 (7.8)	
South Asian	31 (6.2)	10 (5.0)	41 (5.9)	0.759
All other	93 (18.7)	32 (16.0)	125 (17.9)	
Missing	27 (5.4)	10 (5.0)	37 (5.3)	
Previous no. pregnancies				
$\leq 4$	448 (90.1)	172 (86)	620 (89.0)	0.115
$> 4$	49 (9.8)	28 (14)	77 (11.1)	
Previous obstetric history (no. $\geq 24$ -week babies (alive or stillbirth))				
$\leq 3$	429 (86.3)	163 (81.5)	592 (84.9)	0.108
$> 3$	68 (13.7)	37 (18.5)	105 (15.1)	
Mean ( $\pm$ s.d.) BMI ( $\text{kg m}^{-2}$ )	26.0 $\pm$ 6.1	27.0 $\pm$ 6.2	26.3 $\pm$ 6.2	0.078
Pre-existing medical condition				
Yes	244 (49.1)	83 (41.5)	327 (46.9)	0.096
Asthma	64 (26.2)	18 (21.4)	82 (25.0)	0.563
Mental health disorder	59 (24.2)	21 (25.0)	80 (24.4)	0.703
Fertility treatment	58 (11.7)	14 (7.0)	72 (10.3)	0.187
Endocrine disorder	38 (15.6)	10 (11.9)	48 (14.6)	0.412
Hypertension	29 (11.9)	6 (7.1)	35 (10.7)	0.329
Cervical uterine surgery	28 (11.5)	6 (7.1)	34 (10.4)	0.442
Haematological disorders	21 (8.6)	3 (3.6)	24 (7.3)	0.258
Other autoimmune disorder	16 (6.6)	4 (4.8)	20 (6.1)	0.702
Diabetes	14 (5.7)	1 (1.2)	15 (4.6)	0.189
Uterine abnormality	12 (4.9)	4 (4.8)	16 (4.9)	0.954
Urinary tract infection	10 (4.1)	8 (9.5)	18 (5.5)	0.145
Heart condition	9 (3.7)	3 (3.6)	12 (3.7)	0.840
Renal disease	8 (3.3)	1 (1.2)	9 (2.7)	0.502
Risk behaviours during pregnancy				
Smoked	77 (15.5)	22 (11.0)	99 (14.2)	0.197
Used alcohol	13 (2.6)	10 (5.0)	23 (3.3)	0.071
Used drugs	19 (3.8)	3 (1.5)	22 (3.2)	0.122

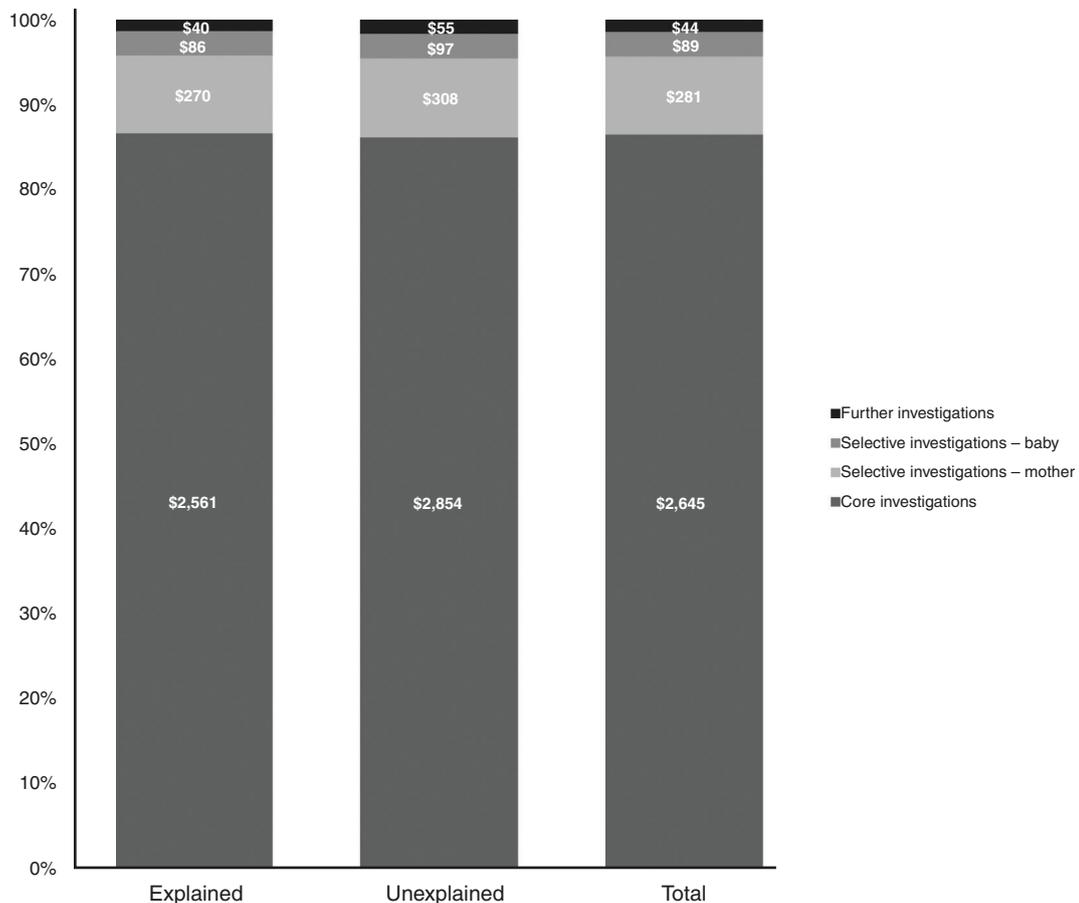
(adjusted  $R^2 = 0.903$ ,  $n = 334$ ) respectively (Table 3). Regardless of an autopsy being performed, costs were not affected by whether the stillbirth cause was unknown within these groups. However, assessing the breakdown among cases with

known causes for stillbirth, costs were significantly lower, by approximately \$193, in the non-autopsy group if the cause was a specific perinatal condition or spontaneous preterm birth (Table 4).

**Table 2. Core investigations by explained or unexplained stillbirths and reason for stillbirth**

Data are given as n (%). \**P* < 0.05

	Explained (n = 497)	Unexplained (n = 200)	Total (n = 697)
<b>Eight core investigations</b>			
Mother's obstetric history	408 (82.1)	167 (83.5)	575 (82.5)
Maternal fetal haemorrhage	311 (62.6)	161 (80.5)*	472 (67.7)
External examination	427 (85.9)	175 (87.5)	602 (86.4)
Clinical photographs	150 (30.2)	82 (41.0)*	232 (33.3)
Autopsy	249 (50.1)	114 (57.0)	363 (52.1)
Placental examination	419 (84.3)	165 (82.5)	584 (83.8)
Placental histopathology	463 (93.2)	181 (90.5)	644 (92.4)
Cytogenetic screening	297 (59.8)	139 (69.5)*	436 (62.6)
No. women with eight core investigations	38 (7.7)	33 (16.5)*	71 (10.2)
No. women with seven core investigations (no autopsy)	47 (9.5)	39 (19.5)*	86 (12.3)
No. women with no core investigations	2 (0.4)	0 (0.0)	2 (0.3)
<b>Reason for stillbirth</b>			
Congenital abnormality	87 (17.5)		
Perinatal infection	52 (10.5)		
Hypertension	28 (5.6)		
Antepartum haemorrhage	65 (13.1)		
Maternal conditions	29 (5.8)		
Specific perinatal conditions	85 (17.1)		
Hypoxic peripartum death	9 (1.8)		
Fetal growth restriction	63 (12.7)		
Spontaneous preterm (<37 weeks gestation)	79 (15.9)		
<b>Total</b>	<b>497 (100.0)</b>		



**Fig. 1.** Proportion of investigations to total costs (AS) by explained, unexplained and all stillbirths.

**Table 3. Results of ordinary least-squares regression by autopsy subgroup**

	Autopsy		No autopsy	
	Coefficient (95% CI)	P-value	Coefficient (95% CI)	P-value
<b>Bivariate models</b>				
Unexplained (yes)	105.55 (28.36, 182.74)	0.01	85.17 (-12.40, 182.74)	0.09
Mother's age	1.10 (-4.86, 7.05)	0.72	-6.40 (-13.31, 0.51)	0.07
Pre-existing condition (yes)	0.02 (-0.03, 0.07)	0.38	0.02 (-0.02, 0.05)	0.29
Born in Australia (yes)	-12.83 (-90.88, 65.23)	0.75	-0.01 (-90.55, 90.54)	1.00
NSW <sup>A</sup>	-62.87 (-155.54, 29.79)	0.18	-195.11 (-309.33, -83.89)	<0.001
Victoria	51.80 (-51.65, 155.26)	0.33	-36.53 (-157.65, 84.60)	0.55
Other state	-94.58 (-199.34, 10.18)	0.08	-232.67 (-362.11, -103.23)	<0.001
Previous obstetric history (≤3 pregnancies)	-18.93 (-135.48, 97.61)	0.75	-60.20 (-167.37, 46.97)	0.27
Alcohol (yes)	0.003 (-0.01, 0.02)	0.77	-0.01 (-0.03, -0.01)	0.27
Photographs of stillborn infant	579.89 (415.78, 744.01)	<0.001	461.22 (333.84, 588.60)	<0.001
Kleihauer-Betke test	200.34 (115.34, 285.34)	<0.001	305.12 (223.32, 386.93)	<0.001
Cytogenetic screening	597.15 (540.40, 653.89)	<0.001	643.27 (593.10, 693.44)	<0.001
No. investigations	245.51 (224.11, 266.91)	<0.001	256.71 (239.13, 274.30)	<0.001
<b>Multivariable models</b>				
Unexplained (yes)	1.28 (-33.14, 35.69)	0.94	-26.35 (-58.00, 5.29)	0.10
Cytogenetic screening	-75.86 (-122.02, -29.70)	<0.001	509.40 (480.67, 538.12)	<0.001
Kleihauer-Betke test	486.79 (448.56, 525.01)	<0.001	-53.07 (-90.38, -15.76)	0.01
No. investigations	35.32 (31.87, 38.76)	<0.001	32.42 (29.53, 35.31)	<0.001
Photographs of stillborn infant	-	-	123.88 (79.17, 168.59)	<0.001
Mean cost	3764.80 (3699.62, 3829.98)	<0.001	246.60 (197.48, 295.73)	<0.001

<sup>A</sup>Reference is Queensland.

**Table 4. Costs by reason for explained stillbirth by autopsy subgroup (n = 497)**

Reason for stillbirth	Autopsy (n = 249)		No autopsy (n = 248)	
	Coefficient (95% CI)	P-value	Coefficient (95% CI)	P-value
Perinatal infection	-78.44 (-225.79, 68.91)	0.295	30.49 (-207.72, 268.69)	0.801
Hypertension	20.03 (-192.28, 232.34)	0.853	-135.91 (-354.60, 82.79)	0.222
Antepartum haemorrhage	-30.80 (-204.08, 142.49)	0.727	-9.80 (-167.59, 148.00)	0.903
Maternal conditions	88.78 (-99.54, 277.09)	0.354	-41.22 (-287.79, 205.35)	0.742
Specific perinatal conditions	3.32 (-144.04, 150.67)	0.965	-191.01 (-346.09, -35.93)	0.016
Hypoxic peripartum death	99.55 (-192.78, 391.89)	0.503	-188.25 (-624.71, 248.21)	0.396
Fetal growth restriction	69.67 (-80.75, 220.09)	0.362	140.98 (-39.95, 321.92)	0.126
Spontaneous preterm birth <sup>A</sup>	-131.13 (-292.31, 30.06)	0.110	-196.40 (-347.60, -45.21)	0.011
Mean cost	4850.12 (4747.83, 4952.42)	0.000	1138.88 (1028.61, 1249.15)	0.000

<sup>A</sup>Defined as at <37 weeks gestation.

## Discussion

We estimated the healthcare costs of stillbirth investigations from a large Australian sample covering a wide representation of hospitals. The mean estimated investigation cost to the health system was A\$4200 per stillbirth, with 76% of stillbirths having five to eight core investigations. The major determinant of costs was whether an autopsy was undertaken. Aside from autopsy and other recommended core investigations, we found costs were not associated with sociodemographic or medical factors that could indicate differences in the health care provided to mothers who had a stillbirth.

Although, until recently, there were many possible investigations to determine the cause of stillbirth, the PSANZ guidance has formalised the essential minimum by recommending eight core investigations, made by consensus and ratified in 2019.<sup>4</sup>

This is after the time stillbirth cases were entered into the database used in the present study, so there was no opportunity for dissemination of the PSANZ guidelines to improve clinical practice. Despite this, a high proportion of cases (76%) undertook most of the core investigations. This would include some cases that would not have required all the core investigations due to an unequivocal cause, with further tests deemed unnecessary. Our findings represent a baseline understanding of overall health system costs, training requirements for physicians and current clinical practices before the PSANZ guidelines. These results offer a benchmark for ongoing professional education and research by emphasising the burden of stillbirths and the role of diagnostic information in optimising resources for future clinical management.

Other cost-analyses of stillbirths have reported varied findings using different approaches and cannot be directly compared with

the findings of the present study, which are a subset of overall stillbirth costs. Callander *et al.* assessed costs to the Australian government and reported an excess of A\$3774 for stillbirths compared with healthy births and an additional A\$1479 in out-of-pocket costs to mothers.<sup>16</sup> That study excluded costs of stillbirth investigations, and so complements the present study. Together, the findings of the present study and those of Callander *et al.*<sup>16</sup> suggest that each stillbirth case in Australia may have a full economic cost of approximately A\$7900. In the UK, the cost of stillbirth investigations was £1804 (2020 A\$4218), which included counselling services,<sup>10</sup> and the total cost of stillbirth to the National Health Service was £4191<sup>6</sup> (2020 A\$8698). Earlier US findings from 2002 estimated the total direct and indirect costs of stillbirth at US\$1447 (2020 A\$2675), of which 45.5% was for indirect costs;<sup>9</sup> later research in 2013 reported a mean ( $\pm$ s.d.) hospital cost of US\$7495  $\pm$  7015) (2020 A\$11 429  $\pm$  10 697) for each stillbirth.<sup>7</sup>

Currently, it is difficult to draw conclusions about whether additional testing and higher costs are worthwhile when each stillbirth is assessed on a case-by-case basis. The marginal costs of each subsequent test and deeper analysis of stillbirth predictors and causes will enable a more detailed value assessment. Based on our findings, crude extrapolation would suggest Australia pays A\$8.8 million per year in stillbirth investigations or A\$28 per live birth (based on 315 000 annual live births<sup>17</sup>). Although this may seem high, it is worth noting that stillbirth investigations have a high diagnostic yield, and many diagnoses are amenable to prevention or changes to management for subsequent pregnancies (e.g. diabetes and hypertension management, folate supplements, additional antepartum fetal monitoring). Considering the full economic burden may be as high as A\$7900 per case, substantial cost benefits may arise from preventing future stillbirths.

Although stillbirth assessment costs to the health system are substantial, they represent just one component of all costs accruing to families, the health system and society more generally.<sup>6</sup> In particular, grief counselling, funerals, time off work and other downstream costs are likely to be far greater than investigation costs alone. Further research and initiatives for reducing preventable stillbirths could be expected to offset investigation costs over time as knowledge grows and clinical practices managing stillbirths improve. Health service providers are called to recognise the broader value of stillbirth investigations, to understand quality care provision and identify potential efficiencies, such as preventing recurrent stillbirths and avoiding high-risk and high-cost pregnancies. In Australia, autopsy funding is not covered by the MBS, and health departments or services fund autopsies through goodwill but often do not cover the average costs. Mistry *et al.* highlighted costs for subsequent births in women with a previous stillbirth (unknown cause) were £3751 compared with £2147 for a healthy birth<sup>10</sup> (2020 A\$8771 vs A\$5020). Further research on how genomic technologies on autopsy tissues<sup>18,19</sup> can help explain pregnancy loss may incur upfront costs to achieve long-term prevention and cost savings.

## Conclusion

Investigations for stillbirth in Australia cost approximately A\$4200 per stillbirth on average and are critical for managing

future pregnancies and preventing more stillbirths. These findings improve our understanding of the costs that may be averted if stillbirths can be prevented through primary prevention initiatives.

## Competing interests

The authors have no competing interests to declare.

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**Appendix 1. List of unit costs for investigations and sources**  
 APC, activated protein C; CSF, cerebrospinal fluid; RBC, red blood cells

	Unit cost (\$A)	Source
<b>Core investigations</b>		
Comprehensive maternal and family history	86.90	MBS item 16401: obstetric specialist, referred consultation – surgery or hospital
Kleihauer–Betke test	34.45	MBS item 65165: examination of a maternal blood film for the presence of fetal RBC (Kleihauer test)
External examination of the baby by attending physician	121.70	MBS item 413: public health physician attendance at consulting rooms
Clinical photographs	42.58	Michalski <sup>9</sup>
Detailed macroscopic examination of the placenta and cord	282.00	Campbell <sup>6</sup>
Placental and amnion biopsy for chromosomal analysis	500.00	Local hospital cost for external specialised laboratory fee
Placental histopathology	97.10	MBS item 72823: level 4 biopsy and examination
Autopsy	3441.15	Mean cost of full complex autopsy and external non-complex autopsy (see Appendix 2)
<b>Selective investigations</b>		
At diagnosis of a fetal death		
Ultrasound scan	60.00	MBS item 55700: obstetric and gynaecological ultrasound
Amniocentesis	149.70	MBS item 16600: amniocentesis
Low vaginal and peri-anal swab	33.75	MBS item 69312: microscopy and culture to detect pathogenic microorganisms from urethra, vagina, cervix or rectum
<b>Blood tests</b>		
Full blood examination		
	16.95	MBS item 65070: erythrocyte count, haematocrit, haemoglobin, calculation or measurement of red cell index, platelet count, leucocyte count and manual or instrument-generated differential count
Serology for cytomegalovirus, toxoplasma, parvovirus B19	15.65	MBS item 69405: microbiological serology during pregnancy for one of rubella, specific syphilis serology, hepatitis B/C or HIV
Rubella and syphilis if not already undertaken in this pregnancy	31.30	MBS item 69405: microbiological serology during pregnancy for one of rubella, specific syphilis serology, hepatitis B/C or HIV
Blood group and antibody screen if not previously undertaken	41.00	MBS item 65096: blood grouping and examination of serum for Rh and other blood group antibodies
Renal function tests including uric acid	9.70	MBS item 66500: renal function tests
Liver function tests and bile acid	17.70	MBS item 66512: five or more liver tests
Thyroid function tests	34.80	MBS item 66719: thyroid function tests
HbA1c	16.80	MBS item 66841: Quantitation of HbA1c performed to diagnose diabetes in asymptomatic high-risk patients
<b>Thrombophilia testing</b>		
Anti-cardiolipin antibodies	25.35	MBS item 65175: test for one of anti-thrombin III deficiency, protein C deficiency, protein S deficiency, lupus anticoagulant or APC resistance
Lupus anticoagulant	25.35	
APC resistance	25.35	
<b>Following birth</b>		
Surface swabs		
	22.00	MBS item 69303: culture microscopy to detect pathogenic microorganisms from nasal, throat, eye and ear swabs
Blood samples from cord or cardiac puncture for investigation of infection	16.95	MBS item 65070: erythrocyte count, haematocrit, haemoglobin, calculation or measurement of red cell index, platelet count, leucocyte count and manual or instrument-generated differential count
Routine Guthrie test	5.07	Authors' assumption of cost
Placental microbiological cultures	48.15	MBS item 69321: microscopy and culture of postoperative wounds, aspirates of body cavities, synovial fluid, CSF or operative or biopsy specimens for the presence of pathogenic microorganisms
<b>Alternative investigations where permission for autopsy is not obtained</b>		
External examination of the baby by an expert	121.70	MBS item 413: public health physician attendance at consulting rooms
Babygram	89.40	MBS item 59503: radiographic examination in connection with pregnancy
Magnetic resonance imaging	201.60	MBS item 63484: scan of the pelvis and upper abdomen
Postmortem ultrasound	60.00	MBS item 55700: obstetric and gynaecological ultrasound
Needle biopsy	2168.15	Estimated price for a limited autopsy (see Appendix 2)
Laparoscopy	2168.15	As above for needle biopsy

**Appendix 2. Cost breakdowns of different types of autopsies**

The unit cost for this study was calculated as the mean cost for a full complex autopsy plus an external non-complex autopsy (=A\$3441.15). The following resources were included in the calculations: staffing (Grade 1 Medical Scientist Year 7; Registrar Year 3; Pathologist Specialist Year 8), work costs (scientist transfer to autopsy suite; admission/paperwork; preparation for autopsy (photography, measurements, imaging); registrar time (preparation, autopsy, macroscopic report, microscopic report); pathologist time (attend autopsy, microscopic report and diagnosis); scientist time (reconstruction, transfer to mortuary, release from mortuary, preparation of histology slides) and consumables (autopsy, histology (block and slide preparation)). IHC, immunohistochemistry; MRI, magnetic resonance imaging; PCR, polymerase chain reaction

	Cost (A\$)
Full non-complex autopsy	
Full postmortem	1976
Skeletal survey/MRI	1310.90
Frozen storage	10
Microbiology	144.45
Placenta histology	97.15
Placenta microbiology	96.10
Total	3634.60
Full complex autopsy	
Full postmortem	2673
Skeletal survey/MRI	1310.90
Karyotyping	527
Frozen storage	10
Placenta histology	97.15
Placenta microbiology	96.10
Total	4714.15
Limited non-complex autopsy	
Limited postmortem	1976
Skeletal survey/MRI	1310.90
Karyotyping	527
Microbiology	144.45
Frozen storage	10
Placenta histology	97.15
Placenta microbiology	96.10
Total	4161.60
Limited complex autopsy	
Limited postmortem	1859
Skeletal survey/MRI	1310.90
Karyotyping	527
Frozen storage	10
Placenta histology	97.15
Placenta microbiology	96.10
Total	3900.15

*(continued next column)**(continued)*

	Cost (A\$)
External non-complex autopsy	
External postmortem	654
Skeletal survey/MRI	1310.90
Placenta histology	97.15
Placenta microbiology	96.10
Frozen storage	10
Total	2168.15
External complex autopsy	
External postmortem	866
Skeletal survey/MRI	1310.90
Placenta histology	97.15
Placenta microbiology	96.10
Placenta karyotyping	527
Frozen storage	10
Total	2907.15
Full complex autopsy	
Hydrops	
Full postmortem	2673
Skeletal survey/MRI	1310.90
Karyotyping	527
Frozen storage	10
Microbiology	144.45
PCR	85
Electron microscopy	180
IHC	90
Placenta histology	97.15
Placenta microbiology	96.10
Total	5213.60
Metabolic storage disease	
Full postmortem	2673
Skeletal survey/MRI	1310.90
Karyotyping	527
Frozen storage	10
Microbiology	144.45
PCR	85
Electron microscopy	1000
Metabolic studies	2260
Fibroblast culture	233
Placenta histology	97.15
Placenta microbiology	96.10
Total	8436.60