Cost–consequence analysis of cause of death investigation in Finland and in Denmark

Ylijoki-Sørensen, Seija; Boldsen, Jesper Lier; Lalu, Kaisa; Sajantila, Antti; Baandrup, Ulrik; Boel, Lene Warner Thorup; Ehlers, Lars Holger; Bøggild, Henrik

Published in:
Forensic Science International

DOI (link to publication from Publisher):
10.1016/j.forsciint.2014.10.032

Publication date:
2014

Document Version
Early version, also known as pre-print

Forensic Science International 245 (2014) 133–142

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Cost–consequence analysis of cause of death investigation in Finland and in Denmark

Seija Ylijoki-Sørensen [a,*], Jesper Lier Boldsen [b], Kaisa Lalu [c], Antti Sajantila [d], Ulrik Baandrup [e], Lene Warner Thorup Boel [a], Lars Holger Ehlers [f], Henrik Bøggild [g]

[a] Department of Forensic Medicine, Aarhus University, Brendstrupgaardsvej 100, 8200 Aarhus N, Denmark
[b] ADBOU, Institute of Forensic Medicine, University of Southern Denmark, Lucernemarken 20, 5260 Odense S, Denmark
[c] National Institute for Health and Welfare, Forensic Medicine Unit, Helsinki Kytösuontie 11, 00300 Helsinki, Finland
[d] Department of Forensic Medicine, Hjelt Institute, Helsinki University, Kytösuontie 11, 00014 Helsinki, Finland, and Institute of Applied Genetics, Department of Molecular and Medical Genetics, University of North Texas Health Science Center, Ft. Worth, Texas, USA
[e] Centre for Clinical Research, Vendsyssel Hospital/Faculty of Medicine, Aalborg University, Bispensgade 37, 9800 Hjørring, Denmark
[f] Department of Business and Management, Danish Center for Healthcare Improvements, Faculty of Social Sciences, Aalborg University, Fibigerstræde 11, Room 73, 9220 Aalborg, Denmark
[g] Public Health and Epidemiology Group, Department of Health Science and Technology, Aalborg University, Niels Jernes Vej 14, 3-209, 9220 Aalborg, Denmark

ARTICLE INFO

Article history:
Received 23 September 2014
Accepted 20 October 2014
Available online 31 October 2014

Keywords:
Manner of death
Cause of death
Autopsy rate
Finland
Denmark
Cost-consequence analysis

ABSTRACT

The 1990s 12–16% total autopsy rate in Denmark has until now declined to 4%, while in Finland, it has remained between 25 and 30%. The decision to proceed with a forensic autopsy is based on national legislation, but it can be assumed that the financing of autopsies influences the decision process. Only little is known about the possible differences between health economics of Finnish and Danish cause of death investigation systems.

The aims of this article were to analyse costs and consequences of Finnish and Danish cause of death investigations, and to develop an alternative autopsy practice in Denmark with another cost profile.

Data on cause of death investigation systems and costs were derived from Departments of Forensic Medicine, Departments of Pathology, and the National Police. Finnish and Danish autopsy rates were calculated in unnatural (accident, suicide, homicide and undetermined intent) and natural (disease) deaths, and used to develop an alternative autopsy practice in Denmark. Consequences for society were analysed.

The estimated unit cost (€) for one forensic autopsy is 3.2 times lower in Finland than in Denmark (€1400 versus €4420), but in Finland the salaries for forensic pathologists working at the National Institute for Health and Welfare are not included in the unit cost. The unit cost for one medical autopsy is also lower in Finland than in Denmark; €700 versus €1070. In our alternative practice in Denmark, the forensic autopsy rate was increased from 2.2% to 8.5%, and the medical autopsy rate from 2.4% to 5.8%. Costs *per* 10,000 deaths were estimated to be 50% (±25%) higher than now; i.e. €3,678,724 (2,759,112–4,598,336), but would result in a lower unit cost for forensic autopsies €3,094 (2,320–3,868) and for medical autopsies €749 (562–936). This practice would produce a higher accuracy of national mortality statistics, which, consequently, would entail higher quality in public health, an accurate basis for decision-making in health politics, and better legislative safety in society.

The implementation of this alternative practice in Denmark requires that legislation demands that forensic autopsy be performed if causality between unnatural death and cause of death cannot be clarified or if cause of death remains unknown. The Danish Health and Medicines Authority should provide guidelines that request a medical autopsy in natural deaths where more information about disease as a cause of death is needed. Our study results warrant similar health economic analyses of different cause of death investigations in other countries.

* Corresponding author. Tel.: +45 87 16 75 00.
E-mail addresses: jboldsen@health.sdu.dk (J.L. Boldsen), kaisa.lalu@thl.fi (K. Lalu), antti.sajantila@helsinki.fi (A. Sajantila), utb@dcm.aau.dk (U. Baandrup), lwb@retsmedicin.au.dk (L.W.T. Boel), lehlers@business.aau.dk (L.H. Ehlers), boggild@hst.aau.dk (H. Bøggild).

http://dx.doi.org/10.1016/j.forsciint.2014.10.032
0379-0738/

1. Introduction

Although it is well known that an autopsy provides accurate information on cause of death (CoD) and manner of death (MoD) [1–11], national legislation and practice governing cause of death investigation (CoDinv) differ in Finland (FI) [12] and Denmark (DK) [13], as seen by a high autopsy rate in FI and a low autopsy rate in DK [14,15]. The decision to proceed with a forensic autopsy in medico-legal CoDinv is based on legislation, but it can be assumed that the financing of the system influences the decision process, although both FI and DK use national CoD statistics to guide public health politics and legislative safety in society.

In DK, the police pay for the forensic autopsies and cadaver transport via their annual, police district budgets [13]. Although annual budgets are based on the estimated costs of different aspects of police work, e.g. forensic autopsies, the final decision on how to spend the money is made by the police in the individual districts. The costs for forensic autopsies hence compete with other costs in the police district, e.g. investment in new equipment necessary to perform police work. In FI, the government finances forensic autopsies, and these do not compete with other costs. The police are responsible for paying for cadaver transport, but this cost is refunded to the police by the government's central administration [12].

Finnish and Danish legislation governing CoDinv use medico-legal investigation in suspected unnatural deaths (accident, suicide, homicide, or undetermined intent), and medical investigation in deaths caused by disease [12,13]. In both countries, the police are responsible for the medico-legal CoDinv. Finnish legislation demands that a forensic autopsy be performed in deaths due to an unnatural MoD or if the CoD remains unclear after police investigation [12]. Forensic autopsy is also performed in cases where the CoD remains unclear but the death is classified as natural. Unnatural deaths where police investigation does not proceed with a forensic autopsy are usually cases in which the CoD is obvious and toxicological investigations would not be informative, e.g. when elderly patients die at the hospital due to pneumonia a few days after surgical treatment of an accidental hip fracture, or when patients die at the hospital because of injuries caused by an accident. In DK, legislation demands that external forensic examination of the body be performed in case of violent deaths or deaths suspected of being unnatural. Investigation proceeds with a forensic autopsy only if the MoD is uncertain, if a crime is suspected, or if the case is otherwise of interest to the police [13].

DK did not always have a low autopsy rate: in 1990, Danish legislation changed which meant that permission from the next-of-kin must be granted to perform an autopsy. The total autopsy rate consequently decreased from 22% to 16% during a 12-month period [16]. In 1996, the total autopsy rate declined further from 16% to 12.5% of all deaths and on Danish annual publication of CoDs was concluded that the increase in the proportion of deaths classified without a specific CoD is due to the low total autopsy rate [17]. This decrease was mainly caused by a decrease in the medical autopsy rate as the forensic autopsy rate has always been low in DK. In the period 1991–1996, about 2.5–3% of total deaths were investigated with a forensic autopsy. Even though forensic pathology has been an accepted medical specialty in DK since 2008, the forensic autopsy rate has decreased; at the moment, the forensic autopsy rate is about 1.5%, and the total autopsy rate is 4% of total deaths.

Our previous study has shown [18] that DK has a significantly high number of ill-defined and unknown Cods where CoDinv does not include a forensic autopsy. More than 80% of these Danish deaths were over 70 years of age at the time of death. The same study found that only few yearly deaths are registered with an unknown CoD in FI, and all these deaths were investigated using a forensic autopsy. We have also shown [19] that the autopsy rate in suicide is low among elderly in DK (5.6%) compared with FI (99.6%), and that the autopsy rate was 89.5% among Danish deaths due to poisoning when these deaths were classified as accidents, but only 20.7% for cases classified as suicides.

Although cost–consequence analysis (CCA) is an important tool in health economics and of particular interest to public health care interventions, it has rarely being used to analyse the impact of CoDinv system to society [20,21]. To the best of our knowledge, no studies have previously assessed the costs and compared the consequences of different existing national CoDinv systems. In addition, we are unaware of the existence of studies exploring an alternative autopsy practice and its costs and consequences in society.

Thus, the aims of the present study were to analyse characteristics and costs of existing CoDinv systems in FI and in DK, and to develop an alternative autopsy practice in DK with a higher autopsy rate and therefore another autopsy cost profile.

2. Materials and methods

2.1. Characteristics of CoD investigation systems in FI and DK

Data on the number of Regional Forensic Centers in FI and University Departments of Forensic Medicine (UNI Dep FM) in DK, and the number of forensic pathologists and trainees working there were extracted from internet pages of Forensic Medicine Units in the National Institute for Health and Welfare (NIFHW) in FI and the UNI Dep FMs in Copenhagen, Odense and Aarhus in DK. Regional Forensic Centers in FI include both NIFHW and UNI Dep FMs, which are working in the same building [22]. Data on the average number of annual Finnish forensic autopsies were obtained from the Finnish NIFHW Internet page. Data on the average number of annual Danish forensic autopsies and external forensic examinations were obtained from the three UNI Dep FMs and from some of the Institutes of Public Health Medical Officers. Data on the average annual number of medical autopsies were obtained from the Departments of Pathology in FI and in DK.

Cost assessment: Costs were defined as the total financial costs (including overhead and cadaver transport). Data on costs were taken from 2012–2013 budgets of Regional Forensic Centers in FI, UNI Dep FMs in DK, Departments of Pathology in FI and DK, and the National Police in FI and DK. Estimates of total costs and unit costs (average cost per autopsy and cadaver transport) were calculated in collaboration with these organizations and departments. All costs are estimated in national currencies and converted from Danish krone (DKK) into Euros (exchanges rate 2014; DKK7.46 = €1).

2.1.1. Existing autopsy rates in FI and in DK

Information from the death certificates was extracted from the mortality registries for 2010. Data from FI covered 90% of all deceased persons who died after four weeks of age. The 10% random exclusion is due to Finnish legislation [12,23,24], which prohibits the use of all deaths in FI at the same time period for research purposes. Simple randomization was performed in Statistics Finland using SAS (Statistical Analysis Software). Data from DK covered all deaths in 2010. To enable a valid comparison, we excluded all deaths occurring before one year of age in both countries. All statistical analyses were conducted using IBM SPSS Statistics software (Statistical Package for the Social Sciences, version 20).

Finnish deaths were divided into eight MoDs according to the Finnish classification (disease, occupational diseases, accident, medical treatment or examination, suicide, homicide, war, and

undetermined intent). Danish deaths were divided into five MoDs according to the corresponding classification used in DK (disease, accident, suicide, homicide, and undetermined intent). In DK, occupational diseases are classified as disease, medical treatment or examination as accident (if CoD is due to a treatment/examination) or disease (if CoD is not due to a treatment/examination), and war is classified as homicide. Underlying CoDs were classified according to the codes of the 10th revision of International Classification of Diseases (ICD-10), which is in use in both countries [25]. Autopsy rates (forensic, medical, and total) were calculated *per* 10,000 deaths to allow comparison between FI and DK. Odds ratios (ORs) with 95% confidence intervals (95% CI) were calculated, and Fisher's exact test was used to calculate two-sided p values (p).

2.1.2. An alternative autopsy practice in DK

The suggested alternative autopsy practice in DK was based on the idea of performing more forensic autopsies in cases where MoD and CoD were unaligned, and to perform more medical autopsies in cases where more information about disease and possible treatment as a CoD was required. Deaths were divided into natural (MoD disease) and unnatural (MoDs accident, suicide, homicide, and undetermined) MoD groups. The alternative autopsy rate calculations were based on Danish and Finnish existing autopsy rates in 2010, the existing Danish law [13], Danish autopsy rates in 1991 and 1996 [16,17], and previous study on national autopsy rates required to achieve reliable mortality statistics [26].

Unnatural deaths that were further investigated with a forensic autopsy in DK were defined as follows: all homicides; all deaths with undetermined MoD; about 90% of deaths classified as suicide and about 85% of deaths classified as accidents. About 50% of otherwise sudden and unexpected deaths, unknown due to a disease, or deaths of persons not treated by a physician during his/her last illness were also further investigated using a forensic autopsy. About 6% of deaths classified as natural were investigated with a medical autopsy. All deaths to be investigated by external forensic examination (including all deaths being further investigated with forensic autopsy) were included in the cost analysis for cadaver transport in the medico-legal CoDinv system in DK.

Cost assessment: The new estimated unit costs for forensic autopsy, external forensic examination, and cadaver transport in the medico-legal CoDinv system and for medical autopsy in DK were calculated using the existing unit costs in FI and in DK. Estimations of scale advantages were based on the assumption of a linear association between unit cost and volume. Since we had no evidence about the 'true' cost model, we used a wide sensitivity range of ±25%. The linear model was considered to be conservative because the association between unit cost and volume normally follows a concave line. The main objective of the direct cost analysis in an alternative autopsy practice in DK was to calculate a possible increase or decrease in total costs following the introduction of an alternative practice.

2.1.3. Consequences of different CoDinv systems

There is no consensus in health economics about the use of a standard scale for estimation of CCA. The principle of evaluation is to identify and to make explicit one set of criteria that may be useful in deciding among different uses for scarce resources [20,21]. In the present study, the consequences for national mortality statistics, public health care, decision-making in health politics, and general and legislative safety were identified and evaluated. For this purpose, a simple consequence scale from zero to two (0 = neither reliable nor accurate, 1 = reliable or accurate, 2 = reliable and accurate) was developed. Scale placement was done after an iterative process where all authors reached agreement.

2.2. Ethics

The study was approved by the Ethics Committee at Statistics Finland (TK-53-728-12) and by the Danish Data Protection Agency (2012-41-0589).

3. Results

3.1.1. Characteristics of CoD investigation systems in FI and DK

The geographical area of FI is 7.9 times larger than DK (Greenland and Faroe Islands excluded), but both countries have about 5.5 million inhabitants, and the crude death rates are also comparable with 10 deaths *per* 1,000 population (Table 1). The NIFHW is the authority in FI responsible for performing all forensic autopsies which are ordered by the police. In DK, the responsible authorities are the UNI Dep FMs which are led by the state pathologists. Forensic pathologists working at the NIFHW in FI perform about 80% (7680/9600 annually) of all forensic autopsies, which means that a forensic pathologist performs 400 forensic autopsies *per* year on average. The number of forensic autopsies at the UNI Dep FMs in FI depends on the agreement between the UNI and the NIFHW; according to this agreement, a forensic pathologist performs 160 forensic autopsies on average at the UNI Dep FM. Forensic pathologists working at the UNI Dep FM in DK perform 30 forensic autopsies *per* year on average.

The average number of medical autopsies *per* year is 2.9 times higher in FI than in DK (3200 versus 1100). We have no data in the present study on the number of clinical pathologists working at the Departments of Pathology in FI and in DK; but in both countries, their main work responsibility is to investigate and find possible diagnoses from samples from living persons.

Cost assessment: The estimated unit cost (€) for one forensic autopsy is 3.2 times lower in FI than in DK (€1,400 versus €4,420). The salaries for forensic pathologists working at the NIFHW are not included in the unit cost for forensic autopsy in FI, but salaries for forensic pathologists and trainees working for the UNI Dep FMs are included. In DK, salaries for forensic pathologists and trainees are included in the unit cost. The Finnish unit cost for one medical autopsy is lower than in DK; €700 versus €1,070.

3.1.2. Existing autopsy rates in FI and in DK

The total autopsy rate was significantly higher in FI (2968/10,000; 29.7%) than in DK (459/10,000; 4.6%) in 2010 (OR, 0.114; 95%CI, 0.103–0.126; $p < 0.001$) (Table 2). Most of the autopsies were forensic in FI (2335/10,000; 23.4% versus medical 633/10,000; 6.3%), while Danish forensic autopsies were outnumbered by medical autopsies (216/10,000; 2.2% versus 243/10,000; 2.4%).

Although the numbers of natural deaths were comparable in DK and FI (9160/10,000; 91.6% in FI and 9600/10,000; 96.0% in DK), the total autopsy rate among the natural deaths was significantly higher in FI (2209/9160; 24.1%) than in DK (346/9600; 3.6%) (OR, 0.118; 95%CI, 0.105–0.132; $p < 0.001$). Only few Finnish deaths (27/9,160; 0.3%) were classified with ill-defined and unknown CoD compared with Danish deaths (384/9600; 4.0%).

The total number of Finnish unnatural deaths (MoD accident: 550, suicide: 190, homicide: 20, and undetermined intent: 30) outnumbered the total number of Danish unnatural deaths (MoD accident: 260, suicide: 110, homicide: 10, and undetermined intent: 20); total 790/10,000; 7.9% in FI and total 400/10,000; 4% in DK. Only one Finnish unnatural death and three Danish unnatural deaths were investigated with a medical autopsy. Thus, the total autopsy rate in these deaths was almost equal to the forensic autopsy rate in both countries; 711/790; 90.0% in FI and 113/400; 28.2% in DK (OR, 0.044; 95%CI, 0.032–0.060; $p < 0.001$). In FI, there

Table 1
Characteristics of the existing medico-legal cause of death investigation (CoDinv) systems and medical autopsies in Finland (FI) and in Denmark (DK) with numbers and estimated costs (€) from the years of 2012–2013 (National Institute for Health and Welfare (NIFHW)).

	FI	DK
Area (km^2)	338,435	43,098[a]
Population in year	2013 5,451,270	5,627,235[a]
Crude death rate in year 2013[b]	10.5	10.2
Medico-legal CoDinv:		
External forensic examination:		
Average number of external forensic examinations *per* year	Not in use	4,700
Number performed by police and medical officers of health	Not in use	3,700
Number performed by police and forensic pathologists	Not in use	1,000
Financing	Not in use	Police
Estimated unit cost (€) for external forensic examination:		
performed by police and medical officers of health	Not in use	310
performed by police and forensic pathologists	Not in use	470
Total costs for external forensic examinations *per* year (€)	Not in use	1,617,000
Forensic autopsy:		
Number of Centers (FI), Departments (DK)	5	3
Average number of forensic autopsies *per* year	9,600	1,150
Average number of forensic pathologists	22[c]	22[d]
Average number of trainees in forensic medicine	11[c]	17[d]
Average number forensic autopsies *per* doctor *per* year	160[e], 400[f]	30[d]
Average work hours *per* autopsy and statement dictation *per* doctor 3[e],	2-3[f]	3-4[d]
Administration	NIFHW	Universities
Financing	NIFHW	Universities, Police
Estimated unit cost (€) for one forensic autopsy	1,400	4,420
includes salary for forensic pathologists	No (NIFHW)	Yes
includes salary for trainees	Yes	Yes
includes other direct costs for an forensic autopsy[g]	Yes	Yes
Total costs for forensic autopsies *per* year (€)	13,440,000	5,083,000
Cadaver transport:		
Transport vehicle	Hearse	Special ambulance
Number of Police Districts	12	12
Financing	Police	Police
Estimated unit cost (€) for one cadaver transport	342	274
Total costs for cadaver transport *per* year (€)	3,283,200	1,287,800[h]
Total costs for medico-legal CoDinv *per* year (€)	16,723,200[i]	7,987,800
Medical autopsy:		
Number of departments	8	13
Average number of medical autopsies *per* year	3,200	1,100
Average work hours *per* autopsy and statement dictation *per* doctor	2	2
Administration	Hospital districts	Hospital districts
Financing	Hospital districts	Hospital districts
Estimated unit cost (€) for one medical autopsy	700	1,070
includes time, buildings, materials, morgue costs	Yes	Yes
Total costs for medical autopsies *per* year (€)	2,240,000	1,177,000
Financing for cadaver transport[j]	Requesting hospital	Requesting hospital

[a] Greenland and Faroe Islands not included in DK.
[b] The average number of deaths during a year *per* 1000 population in both countries.
[c] Six out of 22 forensic pathologists and nine out of 11 trainees in FI are working at the University Departments of Forensic Medicine. Besides forensic autopsies, this work includes responsibilities for teaching, research, clinical forensic medicine, and duty work. Sixteen out of 22 forensic pathologists and two out of 11 trainees in FI are working at the Forensic Medicine Units of NIFHW. Their main work responsibility is the medico-legal CoDinv system, and they perform many forensic autopsies.
[d] All 22 forensic pathologists and 17 trainees in DK are working at the University Departments of Forensic Medicine. Besides forensic autopsies, this work includes responsibilities for teaching, research, clinical forensic medicine, and duty work.
[e] A total of 15 doctors at the University Departments in FI each perform about 160 forensic autopsies *per* year besides other duties.
[f] A total of 18 doctors of NIFHW in FI each perform about 400 forensic autopsies *per* year.
[g] Other direct costs: salaries for assisting personal, buildings, materials, additional investigations, forensic chemistry.
[h] Includes transport costs to and from forensic autopsies and external forensic examinations in DK.
[i] Salaries for forensic pathologists are not included in FI.
[j] No data for cadaver transport costs to and from medical autopsies in FI and in DK.

were only three deaths (3/550; 0.6%) with CoD unspecified accidental death, and they were all investigated using a forensic autopsy (100%). Only one of the totals of 38 Danish unspecified accidental deaths (38/260; 14.6%) was investigated using a forensic autopsy.

3.1.3. An alternative autopsy practice in DK

The total autopsy rate was calculated to be 14.3% (1,426/10,000) in an alternative autopsy practice in DK (Table 3). The forensic autopsy rate of 8.5% (850/10,000) included 500 deaths with unclear CoD and/or MoD and 350 deaths from a total of 400 unnatural deaths. The external forensic examination rate was 14.0% (1400/10,000). It included 1000 deaths with unclear CoD and/or MoD and all 400 unnatural deaths. Deaths in the unnatural MoD group were planned to undergo external forensic examination by the police and a forensic pathologist because almost all of them (350/400; 87.5%) were most likely to be investigated by a forensic autopsy. The cadaver transport rate of 14% (1400/10,000) included all deaths investigated with external forensic examination of the body which, on the other hand, includes deaths further investigated with a forensic autopsy (850/1400).

Cost assessment: The estimated new unit cost (€) for one forensic autopsy was about 1/3 lower than the old unit price

Table 2
Forensic and medical autopsy rates *per* 10,000 deaths in 2010 in Finland (FI) and in Denmark (DK). Deaths are in manner of death (MoD) classifications. MoD disease, accident, and suicide are shown with the most common or specific causes of death (CoD).

MoD/CoD	FI[a]				DK[b]			
	Deaths *n* (%)	Autopsy *n* (%)			Deaths *n* (%)	Autopsy *n* (%)		
		Forensic	Medical	Total		Forensic	Medical	Total
Disease	9160 (91.6)	1577 (17.2)	632 (6.9)	2209 (24.1)	9600 (96.0)	106 (1.1)	240 (2.5)	346 (3.6)
Circulatory system	4067 (44.4)	1122 (27.6)	317 (7.8)	1439 (35.4)	2784 (29.0)	50 (1.8)	75 (2.7)	125 (4.5)
Neoplasms	2345 (25.6)	108 (4.6)	134 (5.7)	242 (10.3)	3014 (31.4)	6 (0.2)	63 (2.1)	69 (2.3)
Digestive system	485 (5.3)	184 (38.0)	79 (16.2)	263 (54.2)	528 (5.5)	12 (2.3)	33 (6.2)	45 (8.5)
Respiratory system	385 (4.2)	66 (17.1)	32 (8.2)	98 (25.3)	1123 (11.7)	4 (0.4)	26 (2.3)	30 (2.7)
Endocrine, nutritional, metabolic	110 (1.2)	26 (23.6)	12 (10.5)	38 (34.1)	336 (3.5)	5 (1.5)	8 (2.5)	13 (4.0)
Ill-defined or unknown cause	27 (0.3)	25 (92.0)	0	25 (92.0)	384 (4.0)	9 (2.4)	3 (0.8)	12 (3.2)
Occupational disease	30 (0.3)	29 (95.6)	0	29 (95.6)	Not in use	Not in use	Not in use	Not in use
Accident	550 (5.5)	471 (85.7)	1 (0.2)	472 (85.9)	260 (2.6)	71 (27.2)	3 (1.2)	74 (28.4)
Poisoning	138 (25.1)	137 (99.5)	0	137 (99.5)	35 (13.6)	32 (90.3)	0	32 (90.3)
Traffic	69 (12.5)	68 (98.7)	0	68 (98.7)	55 (21.2)	15 (26.9)	0	15 (26.9)
Unspecified accidental death	3 (0.6)	3 (100)	0	3 (100)	38 (14.6)	1 (1.5)	0	1 (1.5)
Medical treatment or examination	20 (0.2)	19 (93.2)	0	19 (93.2)	Not in use	Not in use	Not in use	Not in use
Suicide	190 (1.9)	189 (99.4)	0	189 (99.6)	110 (1.1)	14 (12.4)	0	14 (12.4)
Hanging and Suffocation	59 (31.0)	59 (100)	0	59 (100)	41 (37.5)	2 (3.8)	0	2 (3.8)
Poisoning	55 (28.9)	55 (100)	0	55 (100)	35 (31.3)	8 (23.3)	0 8 (23.3)	
Homicide	20 (0.2)	20 (100)	0	20 (100)	10 (0.1)	10 (100)	0	10 (100)
War	0	0	0	0	Not in use	Not in use	Not in use	Not in use
Undetermined intent	30 (0.3)	30 (100)	0	30 (100)	20 (0.2)	15 (74.3)	0	15 (74.3)
Total:	10,000 (100)	2335 (23.4)	633(6.3)	2968 (29.7)	10,000 (100)	216 (2.2)	243 (2.4)	459 (4.6)

[a] Data from FI are based on a random 90% sample of deaths occurring after one year of age in 2010.
[b] Data from DK are based on a 100% sample of deaths occurring after one year of age in 2010.

(±25%) in an alternative autopsy practice in DK (€3094; 2320–3868 versus €4420). The new unit cost for one medical autopsy was also lower than the old unit price in DK; €749 (562–936) versus €1070. The total estimated cost for the alternative medico-legal CoDinv system in DK was €3,247,300 *per* 10,000 deaths and €16,236,500 *per* 50,000 deaths, which was two times more than in the existing CoDinv system in DK (Table 1; €7,987,800). The total estimated cost for medical autopsies in an alternative autopsy practice was €2,157,120, which is also an increase from the existing estimated cost (Table 1; €1,177,000). The unit cost for cadaver transport (€192; 144–240) included transport both to external forensic examination and to forensic autopsy, because it was not possible to identify different unit costs for these.

3.1.4. Consequences of different CoDinv systems

The overall conclusion (Table 4) is that because of a higher rate of medico-legally investigated unclear deaths and a higher medical autopsy rate in the alternative autopsy practice in DK, the consequences for general and legislative safety were evaluated to be as reliable and accurate as it is in FI. This conclusion is reached because of the more frequent use of external forensic examination and assuming that 87.5% (Table 3) of unnatural deaths are further investigated using a forensic autopsy in DK.

The consequences for national mortality statistics, public health care, and decision-making in health politics were evaluated to be reliable and/or accurate (1–2) in an alternative autopsy practice in DK. Although external forensic examination in DK is assumed to be a good supplement to the medico-legal CoDinv system, it does have a number of disadvantages, e.g. there is a small possibility that some CoD statements are only based on this examination and are not correct.

4. Discussion

Differences in legislation concerning medico-legal CoDinv and different financing practices for forensic autopsies are reflected in a high forensic autopsy rate in FI and a low rate in DK. The main difference between the existing Finnish and Danish systems is that legislation in DK is based on external forensic examination of the body, which, in practice, is not followed by a CT scan or blood samples for toxicological analysis. Investigation only proceeds with a forensic autopsy in DK if the MoD is uncertain, if a crime is suspected, or if the case is of interest to the police. Thus, for example, if the external examination concludes that the MoD is suicide, a forensic autopsy will most likely not be performed. This practice is followed even in cases where the CoD is undetermined. The fact that the next-of-kin cannot appeal the decision made during the external forensic examination of the body in DK can entail frustration. In FI, investigation almost always proceeds with a forensic autopsy in deaths due to an unnatural MoD (accident, suicide, homicide, and undetermined intent), or if the CoD remains unknown after police investigation. The last criterion includes deaths with a natural MoD (disease).

The error rate in determining CoD after external forensic examination can reach 28% in natural deaths [27]. About 33% of unnatural deaths have previously been found with minor to severe missed injuries, which have been overlooked using external forensic examination, and first discovered at a forensic autopsy [28]. Generally, when a CoD is obscure or unknown before autopsy, only few remain unknown after a forensic autopsy [29,30]. Recommendations for the harmonization of the CoD investigation have been made in Europe and in the USA [31,32]. However, Denmark, the Netherlands and Germany reserve the right of their own governments to choose whether to comply with the recommendations that autopsies should be performed in all suspected unnatural deaths.

Previous studies have shown that a long distance to the departments of forensic medicine could explain the discrepancies in autopsy rates, possibly because of higher costs for cadaver transport [10,33]. This seems not to be the case in FI, which is about eight times the size of DK, has only five Regional Forensic Centers compared with three Danish UNI Dep FMs, and has a high forensic autopsy rate (2335/10,000; 23.4%) compared with the Danish rate (216/10,000; 2.2%). FI uses hearse vehicles that can transport more than one deceased person to the Regional Forensic Centers. After a forensic autopsy has been performed, the deceased person is transported to a morgue at the nearby hospital where the body is

Table 3
Costs of medico-legal cause of death investigation (CoDinv) systems and medical autopsies in an alternative autopsy practice in Denmark (DK). Deaths are *per* 10,000 deaths and divided into natural (disease) and unnatural (accident, suicide, homicide, undetermined) manner of death (MoD) groups. Existing average (old) numbers and rates of deaths are presented. Estimated existing unit costs are informed. New estimated unit costs are based on an estimated 30% decrease in old costs, with 25% intervals (1€ = 7.46 DKK).

Components of CoDinv with inclusions criteria	MoD groups *n* (%) Natural	Unnatural	Total	Old	(€) Unit cost Estimated new (±25%)	(€) Estimated new total cost Per 10,000 deaths (±25%)
Deaths *n* (%) in 2010 in DK:	9600 (96.0)	400 (4.0)	10,000 (100)			
Medico-legal CoDinv:						
External forensic examination:						
Performed by police and medical officer of health (old *n* about 740): deaths that are sudden and unexpected, with unknown cause of death, unknown due to disease, or deaths of persons not treated by physician during his/her last illness.	1000 (10.4)[a]			310	217 (163–271)	217,000 (163,000–271,000)
Performed by police and forensic pathologist (old *n* about 200): all unnatural deaths (in 2010 in DK: 260 accidents, 110 suicides, 10 homicides and 20 undetermined MoDs).	400 (100)[a]			470	329 (247–411)	131,600 (98,800–164,400)
External forensic examination rate (old n about 940; rate 9.4%):			1400 (14.0)[a]			348,600 (261,800–435,400)
Forensic autopsy:						
About 50% (500/1,000) of deaths that are sudden and unexpected, with unknown cause of death, unknown due to disease, or deaths of persons not treated by physician during his/her last illness.	500 (5.2)[a]					
About 85%b (221/260) of deaths classified as accident.		221 (55.3)[b]				
About 90%b (99/110) of deaths classified as suicide.		99 (24.8)[b]				
100%[c] (10/10) of deaths classified as homicide.		10 (2.5)[c]				
100%[c] (20/20) of deaths classified as undetermined.		20 (5.0)[c]				
Forensic autopsy rate (old n about 216; rate 2.2%):			850 (8.5)[d]	4420	3,094 (2,320–3,868)	2,629,900 (1,972,000–3,287,800)
Cadaver transport:						
All deaths investigated by external forensic examination and this includes 850 deaths being further investigated with forensic autopsy (old *n* about 940):			1400 (14.0)	274	192 (144–240)	268,800 (201,600–336,000)
Total costs for medico-legal CoDinv per year (€)						3,247,300 (2,435,400–4,059,200)
Medical autopsy:						
About 6%[a] of deaths due to a disease.	576(6.0)[a]					
None of unnatural deaths.		0[a]				
Medical autopsy rate and costs (old *n* about 243; rate 2.4%):			576 (5.8)[a,d]	1070	749 (562–936)	431,424 (323,712–539,136)
Total autopsy rate and cost (old total n 459; rate 4.6%):	1076 (11.2)	350 (87.5)	1426 (14.3)[d]			3,678,724 (2,759,112–4,598,336)

[a] Reference [24]: Lahti RA (2005) Autopsy and cause-of-death information, in: dissertation by Lahti RA, From findings to Statistics: an assessment of Finnish medical cause-of-death information in relation to underlying-cause coding, Academic dissertation, Department of Forensic Medicine, University of Helsinki, Finland. https://helda.helsinki.fi/handle/10138/20374 ISBN 952-10-2754-1 (pdf), pp. 58-61.
[b] Finnish forensic autopsy rates in 2010 (Table 2).
[c] Reference [13]: Act on the External Examination of the Body and on the Autopsy (Nr. 913; 54-57). Ministry for Internal Affairs and Ministry of Health, Denmark (in Danish).
[d] References [16,17]: National Board of Health. Causes of Death in Denmark 1991 and 1996. Copenhagen, National Board of Health.

Table 4
Consequences[a] for national mortality statistics, public health care, decision-making in health politics, and general and legislative safety of medico-legal cause of death investigations (CoDinv) and medical autopsies, in existing systems in Finland (FI), in Denmark (DK), and in an alternative autopsy practice in DK. Scale of consequences has been developed and spans 0-2[b]. Consequence.

Consequences on/Statement	FI	DK	Alternative practice DK
National mortality statistics: A high total autopsy rate in FI gives reliable and accurate CoD information. An alternative autopsy practice in DK uses forensic autopsy to investigate most unclear deaths, but because of the use of external forensic examination, there is a possibility that some CoD statements are only based on this examination and are not totally correct. It must be assumed that the existing high number of ill-defined and unknown CoDs in DK is going to decrease because of a higher rate of forensic autopsies.	2	0	1–2
Public health care: The high forensic autopsy rate in FI leads to a high quality control in health care, e.g. cases with unclear causality between the diagnosis, reason for hospital stay, illness, treatment procedures or possible side effects, and, finally, the death, are all cases which are investigated with a forensic autopsy including a forensic chemical analysis. The existing CoDinv system in DK leads to a very low forensic autopsy rate. At the same time, the medical autopsy is rarely used. This means that most deaths happening at the hospital or after surgery are not always investigated using an autopsy. An alternative autopsy practice enables better possibilities to register these deaths in the system, but it requires that medical doctors are informing police of possible medico-legal deaths or requesting a medical autopsy from the next-of-kin.	2	0	1–2
Decision-making in health politics: Information from mortality statistics is used in health politics to decide and prioritize different campaigns in public healthcare. National CoD gives data, e.g. on mortality due to a specific disease which demands interventions by health politics. Inaccurate mortality statistics lead to an inaccurate information basis for this kind of decision-making in health politics. When mortality statistics are reliable, resources in public health care can be used more efficiently towards the needed interventions. It must be assumed that FI has accurate mortality statistics to base decision-making in health politics. Mortality statistics in DK will become more accurate in the alternative autopsy practice by more precise CoDs.	2	0	1–2
General and legislative safety: FI and DK will become more comparable after an alternative autopsy practice is established in DK. This is because legislation is going to be more precise on defining the cases to be investigated with a forensic autopsy in DK. Data from all accidents and other unnatural deaths are going to be used better for planning preventive safety procedures in traffic, at home, and at work. Identification of homicides and getting proof material for crimes are also going to be better because of a high forensic autopsy rate in unnatural deaths.	2	1	2

Other abbreviations: cause of death (CoD), manner of death (MoD).
[a] Consequences evaluation is based on effectiveness and quality of different CoDinv systems from the societal point of view.
[b] Consequences scale: 0 = neither reliable nor accurate, 1 = reliable or accurate, 2 = reliable and accurate.

preserved until the funeral. This has minimized the cost for the transport and maximized the benefit of the existing resources in FI.

In FI, the responsible authority for performing forensic autopsies is the NIFHW, and only a small number of autopsies take place at the UNI Dep FM [22]. In this way, it is possible to perform many forensic autopsies in FI because the main responsibility of forensic pathologists working for the NIFHW is to determine the CoD in cooperation with the police. The number of forensic autopsies performed *per* forensic pathologist working for the NIFHW varies, but the average number is 400 *per* year. The NIFHW is also the guiding and supervising authority of the CoDinv; forensic pathologists guide medical doctors and police in the CoD investigation and control the death certificates completed by the medical doctors in their districts.

In DK, all three Dep FMs are administrated by the UNI, and forensic pathologists working in the departments have other work duties that are comparable to those performed by the Finnish forensic pathologists working at the UNI Dep FM, i.e. teaching, clinical forensic medicine, and duty work. Although the work duties are the same, a Danish forensic pathologist performs 30 forensic autopsies *per* year on average, while a Finnish forensic pathologist at the UNI Dep FM performs 160 forensic autopsies *per* year on average. The number of Finnish forensic autopsies performed at the UNI Dep FM is agreed with the NIFHW, which has the responsibility for forensic autopsies in FI. Previous studies have found that a forensic pathologist should not perform more than 250 forensic autopsies annually, and that more than three forensic autopsies in a day can decrease the quality of the CoDinv work [34]. Forensic medicine as a medical specialty includes clinical forensic medicine, which is a large work duty in DK. Despite this, we speculate whether forensic pathologists in DK get sufficient training and education in different types of autopsies and sufficient experience in establishing the MoD and CoD. The Finnish system can be criticized for performing too many forensic autopsies with too little resources, which may entail quality problems.

Medical pathology is administrated the same way in FI and DK. Clinical pathologists have many work responsibilities, e.g. diagnosis of histopathological changes and possible diseases in tissue samples from living persons, and performing medical autopsies is therefore a minor work duty. Additionally, previous studies from different countries have shown that the worldwide medical autopsy rate is decreasing [4]. Although medical autopsy is known to be the final method to verify a diagnosis of a disease as a CoD [6,8], the medical autopsy rate is low in DK (2.4%) compared with FI (6.3%).

The estimated unit cost for a forensic autopsy is lower in FI (€1400) than in DK (€4420), which we assume is owing to the lower unit costs in FI because of economies of scale. This difference in unit cost could be explained partly by the fact that the salaries of forensic pathologists working for the NIFHW are not included in unit cost for forensic autopsy in FI, but salaries for forensic pathologists and trainees working for the UNI Dep FMs are. In DK, salaries for forensic pathologists and trainees are included in the unit cost.

Overall, the Danish government annually spends half a much (€7,987,800) as FI (€16,723,200) on the medico-legal CoDinv system, but the forensic autopsy rate "output" is 2.2% in DK compared with 23.4% in FI. Furthermore, ill-defined and unknown CoDs are more frequent in DK than in FI (2000 versus 100) and the Finnish cases were all investigated with a forensic autopsy [18].

Only 400 deaths *per* 10,000 deaths in DK were classified as unnatural (accident, suicide, homicide, or undetermined intent) in 2010. Based on the data from the Finnish mortality statistics and the consistently high forensic autopsy rate in FI, there are about 4000 unnatural deaths of a total of about 49,000 annual deaths in FI

[26]. FI and DK are comparable politically, economically, and structurally. We may therefore conclude that of the total of about 50,000 annual deaths in DK, about 700–800 deaths *per* 10,000 deaths should be classified as unnatural. In his thesis [26], Lahti also concluded that among about 45,000 Finnish annual natural deaths, about 5000 are sudden and unexpected deaths. Adjusting these numbers to DK, there should be about 1000 deaths *per* 10,000 deaths that are sudden and unexpected or have an unknown CoD. Our study results showed that in 2010, the code for ill-defined and unknown CoD was used in 384 deaths *per* 10,000 deaths in DK, and only nine were investigated with a forensic autopsy. We cannot conclude as to how these rest/missing 616 sudden and unexpected deaths *per* 1000 total deaths were categorized in the Danish national mortality statistics.

The alternative autopsy practice includes all sudden and unexpected deaths be medico-legally investigated. Apart from external forensic examination such investigation includes about 50% (500/1000) of cases with a forensic autopsy investigation. Based on this, it can be assumed that the number of ill-defined and unknown CoDs will fall in DK.

All unnatural deaths were assumed to be investigated with an external forensic examination and to proceed with a forensic autopsy in 85–100% of cases. Forensic pathologists should be responsible for this part of the external forensic examinations because they are specialized in detecting external and internal injuries, which is needed in the external forensic examination of the body. Furthermore, it was assumed that external forensic examinations could take place at the UNI Dep FMs in order to save on possible extra transport.

Lahti's thesis from 2005 [26] also showed that a national medical autopsy rate of 6-8% is acceptable to produce reliable CoD statistics. This is possible owing to the current frequent medical records. Our study showed that FI had a medical autopsy rate of 6.3% (633/10,000 deaths) in 2010. Danish medical autopsy rate of 5.8% (576/10,000 deaths) was assumed to give a better accuracy of CoDs in deaths classified as natural.

The unit costs for forensic autopsy in FI increased by about 30% (€981 to €1401) in the 2010–2013 period because of a 20% decrease in the number of annual forensic autopsies (11,948–9617 = 2,331) [22]. Even though the increase in the number of annual forensic autopsies in DK was about 5% higher than in FI (3100–2331 = 769), this was not taken in account because Danish unit costs for forensic autopsies include salaries for forensic pathologists and Finnish unit costs do not include the salaries for forensic pathologists working in the NIFHW. The range ±25% was calculated to show that this new unit cost in DK is an estimate and not an exact figure. It can be assumed that, in reality, the new unit costs are closer to −25% of the estimates. Overall costs increased in DK; but the accuracy of mortality statistics would improve.

The weakness of the consequences evaluation in this study is that the consequences are based on a subjective quality evaluation; the consequences for national mortality statistics, public health care, decision-making in health politics, and general and legislative safety in an alternative autopsy practice in DK, were stated to be almost as good as they are assumed to be in FI right now (statements in Table 4). Although we assume that FI and DK are comparable from a societal point of view, some national cultural and historical dimensions are difficult to compare internationally, and this fact may introduce a methodological bias because two countries with different price levels and resources are compared.

A partly unexpected result of our study was that the only way to implement this alternative autopsy practice in DK is to change existing legislation governing CoDinv in DK [13]; legislatively, if causality between unnatural death and CoD cannot be clarified, or if CoD remains unknown, investigation of CoD has to include a forensic autopsy. The medical autopsy rate could be increased by new guidelines from the Danish Health and Medicines Authority (DHMA) that request a medical autopsy in natural deaths where more information about disease as a CoD or other information about diseases is needed. Overall, the aspect of unknown CoD has to be included in the Danish CoDinv legislation, meaning that external forensic examination should be performed to investigate all unnatural deaths or sudden, unexpected deaths with an unknown CoD, even if they have been preliminarily classified as caused by disease.

Because of the high total autopsy rate in FI, it could be concluded that Finnish legislation on the CoDinv system is quite clear on defining cases to be investigated with a forensic autopsy. As previously mentioned, FI has seen a 20% decline in forensic autopsies in the period 2010–2013, and this has been mostly in cases of natural deaths. This is due to a NIFHW national plan for the years of 2000–2015 which aims to decrease forensic autopsies by a total of 30% because too many forensic autopsies are being performed and because there are too few forensic pathologists in FI to cope with the present workload [21]. The methods used to achieve this 20% decrease do not include a change in the existing Finnish legislation. Forensic pathologists working for the NIFHW have been giving extra guidance to police and medical doctors for interpretation of the law in cases of natural death, and where it is possible to find a CoD from a medical history, and where the police do not find suspicious things when investigating the scene where needed. The overall goal in the NIFHW's plan is to reduce the workload for scarce forensic pathologist resources and thereby hopefully increase work quality. From this point of view, it can be concluded that an external forensic examination of the body is a good supplement in the medico-legal CoDinv system for selection of those deaths that need to be investigated using a forensic autopsy. Perhaps, external forensic examination could be implemented in the Finnish medico-legal CoDinv system for investigation of all sudden and unexpected deaths.

An alternative autopsy practice in DK would increase the number of forensic autopsies from the existing about 30 annual autopsies *per* forensic pathologist to about 100 autopsies (39 forensic pathologists and trainees performing a total of 4200 annual forensic autopsies). It is assumed that the three existing UNI Dep FMs can manage these autopsies, but this new forensic autopsy rate demands new assisting personnel and material investments. In DK, 13 Departments of Pathology are equipped to perform autopsies. Some of them have closed their morgues because, currently, there are no autopsies or because this activity has been centralized to larger departments. It is assumed that these buildings/morgues can accommodate the resources needed to perform the suggested number of medical autopsies (about 2800 annual medical autopsies). The new overhead is going to cover the new costs for assisting personnel and material investments.

A strength of the present study is that the modeling of the alternative autopsy practice in DK is based on the DHMA publications on annual CoDs from the 1990s [16,17], where it was concluded that a total autopsy rate of 12.5% was already impairing the validity of the Danish CoD registration. The new total autopsy rate of 14.3% is only a little higher, but with 8.5% forensic autopsy rate will likely achieve a higher accuracy of CoDs than the 2.5–3% forensic autopsy rate of the 1990s. Forensic pathology has since then been accepted as an independent medical specialty in DK, which means better resources to medico-legal CoDinv and better possibilities to perform forensic autopsies. There are only few previous published studies analysing both forensic and medical autopsies, but they mostly evaluate the importance of medical autopsies and discuss the consequences for quality of health care because of a decrease in medical autopsy rate [9,35–37].

5. Conclusion

Our study suggests that by implementing the alternative autopsy practice in DK, the forensic autopsy rate would increase from 2.2% (216 deaths) to 8.5% (850 deaths) and the medical autopsy rate would increase from 2.4% (243 deaths) to 5.8% (576 deaths) *per* 10,000 deaths. Costs *per* 10,000 deaths were estimated to be 50% (±25%) more than now; €3,678,724 (2,759,112–4,598,336), but would result in a lower unit cost for forensic autopsies; new €3,094 (2320–3868) versus old €4,420, and for medical autopsies; new €749 (562–936) versus old €1070. As a consequence, an alternative autopsy practice in DK would produce a higher accuracy of national mortality statistics, which, consequently, would entail higher quality in public health, an accurate basis for decision-making in health politics, and better legislative safety in society.

To achieve this, the existing legislation concerning medico-legal CoDinv in DK has to be amended; all unnatural deaths and sudden, unexpected deaths with unknown CoD, although preliminarily classified as caused by disease, have to be investigated using external forensic examination. If causality between unnatural deaths and CoD cannot be clarified with external forensic examination (e.g. in intentional or accidental poisonings), or the CoD remains unknown, investigation has to include a forensic autopsy. Increasing the medical autopsy rate requires guidelines from the DHMA; medical doctors should request a medical autopsy in natural deaths where more information of disease as a CoD or further information of the disease is needed. Our study results warrant similar health economic analyses of different cause of death investigation systems in other countries.

Conflict of interest

The authors declare that there are no conflicts of interest.

Foundations

The study was funded by the A.P. Moller Foundation for the Advancement of Medical Science and by Aase and Ejnar Danielsen's Foundation. Seija Ylijoki-Sørensen was funded by the Frimodt-Heineke Foundation and the Graduate School of Health Sciences, Aarhus University, Denmark. Antti Sajantila was funded by Finnish Foundation's Professor Pool (Paulo Foundation).

Acknowledgments

We wish to thank the following institutes and authorities for providing financial data used in this study; Departments of Forensic Medicine at the Universities of Southern Denmark, Copenhagen and Aarhus, Denmark; the National Institute for Health and Welfare; the Forensic Medicine Unit, Helsinki, Finland; the National Police, Copenhagen, Denmark; and the National Police, Helsinki, Finland.

We also wish to thank Irmeli Penttila, Antti Katainen, Jari Hellanto, and Raija Maljanen of Statistics Finland, for providing the Finnish cause-of-death data (permit TK-53-728-12); Morten Munk Marcussen of SSI (Statens Serum Institut), Denmark, for the Danish cause-of-death data (permit FSEID-00000296); and Morten Pilegaard for linguistic revision.

References

[1] P.N. Nemetz, J. Ludwig, L.T. Kurland, Assessing the autopsy, Am. J. Pathol. 128 (2) (1987) 362–379.
[2] Council on scientific affairs, American Medical Association, Autopsy, a comprehensive review of current issues, JAMA 17 (258) (1987) 364–369.
[3] J.E. Hooper, S.A. Geller, Relevance of the autopsy as a medical tool: a large database of physician attitudes, Arch. Pathol. Lab. Med. 131 (2) (2007) 268–274.
[4] J. Xiao, G.R. Krueger, L.M. Buja, M. Covinsky, The impact of declining clinical autopsy: need for revised healthcare policy, Am. J. Med. Sci. 337 (1) (2009) 41–46. http://dx.doi.org/10.1097/MAJ.0b013e318184ce2b.
[5] S.D. Ferrara, E. Baccino, T. Bajanowski, R. Boscolo-Berto, M. Castellano, R. De Angel, et al., Malpractice and medical liability. European guidelines on methods of ascertainment and criteria of evaluation, Int. J. Legal Med. 127 (3) (2013) 545–557. http://dx.doi.org/10.1007/s00414-013-0836-5.
[6] S. Sblano, A. Arpaio, F. Zotti, A. Marzullo, A. Bonsignore, A. Dell'Erba, Discrepancies between clinical and autoptic diagnoses in Italy: Evaluation of 879 consecutive cases at the Policlinico of Bari teaching hospital in the period 1990-2009, Ann. Ist. Super Sanita 50 (1) (2014) 44–48. http://dx.doi.org/10.4415/ANN_14_01_07.
[7] E.C. Burton, The autopsy: a professional responsibility in assuring quality of care, Am. J. Med. Qual. 17 (2) (2002) 56–60. http://dx.doi.org/10.1177/106286060201700203.
[8] T. Silfvast, O. Takkunen, E. Kolho, L.C. Andersson, P. Rosenberg, Characteristics of discrepancies between clinical and autopsy diagnoses in the intensive care unit: a 5-year review, Intensive Care Med. 29 (2) (2003) 321–324. http://dx.doi.org/10.1007/s00134-002-1576-z.
[9] D.E. Harrington, E.A. Sayre, Managed care and measuring medical outcomes: did the rise of HMOs contribute to the fall in the autopsy rate? Soc. Sci. Med. 70 (2) (2010) 191–198. http://dx.doi.org/10.1016/j.socscimed.2009.09.018.
[10] B.G. Winkel, A.G. Holst, J. Theilade, I.B. Kristensen, J.L. Thomsen, H.P. Hougen, et al., Differences in investigations of sudden unexpected deaths in young people in a nationwide setting, Int. J. Legal Med. 126 (2) (2012) 223–229. http://dx.doi.org/10.1007/s00414-011-0602-5.
[11] B. Brinkmann, Harmonization of medico-legal autopsy rules. Committee of Ministers. Council of Europe, Int. J. Legal Med. 113 (1) (1999) 1–14. http://dx.doi.org/10.1007/s004140050271.
[12] Act on the Investigation of the Cause of Death (459/1973). Parliament, Finland. (in Finnish).
[13] Declaration of Laws in the Public Health. Act on the External Examination of the Body and on the Autopsy (Nr. 913; 54-57). Ministry for Internal Affairs and Ministry of Health, Denmark. (in Danish).
[14] S.T. Larsen, N. Lynnerup, Medico-legal autopsies in Denmark, Dan. Med. Bull. 58 (3) (2011) A4247.
[15] P. Saukko, Medicolegal investigative system and sudden death in Scandinavia, Nihon Hoigaku Zasshi 49 (6) (1995) 458–465.
[16] Causes of Death in Denmark 1991. Copenhagen, National Board of Health, Denmark.
[17] Causes of Death in Denmark 1996. Copenhagen, National Board of Health, Denmark.
[18] S. Ylijoki-Sørensen, J.L. Boldsen, L.W.T. Boel, H. Bøggild, K. Lalu, A. Sajantila, Autopsy rate in suicide is low among elderly in Denmark compared with Finland, Forensic Sci. Int. 244 (2014) 158–165. http://dx.doi.org/10.1016/j.forsciint.2014.08.035.
[19] S. Ylijoki-Sørensen, A. Sajantila, K. Lalu, H. Bøggild, J.L. Boldsen, L.W.T. Boel, Coding ill-defined and unknown cause of death is 13 times more frequent in Denmark than in Finland, Forensic Sci. Int. 244C (2014) 289–294. http://dx.doi.org/10.1016/j.forsciint.2014.09.016.
[20] J.A. Mauskopf, J.E. Paul, D.M. Grant, A. Stergachis, The role of cost-consequence analysis in healthcare decision-making, Pharmacoeconomics 13 (3) (1998) 277–288. http://dx.doi.org/10.2165/00019053-199813030-00002.
[21] M.F. Drummond, M.J. Sculpher, G.W. Torrance, B.J. O'Brien, G.L. Stoddart, Cost analysis, in: Methods for the Economic Evaluation of Health Care Programmes, 3rd ed., Oxford University Press Inc, New York, 2005, pp. 55–72.
[22] Development in forensic medicine 2000–2015 (2011). National Institute for Health and Welfare, Helsinki, Finland. (in Finnish).
[23] Act on the Openness of Government Activities (621/1999). Ministry of Justice, Finland. http://www.finlex.fi/en/laki/kaannokset/1999/en19990621.pdf.
[24] Statistics Act (280/2004). Parliament, Finland. http://www.stat.fi/meta/lait/2013-09-02_tilastolaki_en.pdf.
[25] World Health Organization, Cost analysis, 2010th ed., International Statistical Classification of Diseases and Related Health Problems (ICD-10), 2, World Health Organization, 2011 10th revision, http://apps.who.int/classifications/icd10/browse/2010/en.
[26] R.A. Lahti, Autopsy and cause-of-death information, in: Dissertation by R.A. Lahti, From findings to statistics: an assessment of Finnish medical cause-of-death information in relation to underlying-cause coding, Department of Forensic Medicine, University of Helsinki, Finland, 2005, , pp. 58–61https://helda.helsinki.fi/handle/10138/20374 ISBN 952-10-2754-1. (pdf).
[27] M.B. Nashelsky, C.H. Lawrence, Accuracy of cause of death determination without forensic autopsy examination, Am. J. Forensic Med. Pathol. 24 (4) (2003) 313–319, DOI 10.1097/01.paf.0000097857.50734.c3..
[28] T.D. Light, N.A. Royer, J. Zabell, M.B. Le, T.A. Thomsen, G.P. Kealey, et al., Autopsy after traumatic death - a shifting paradigm, J. Surg. Res. 1 (167) (2011) 121–124. http://dx.doi.org/10.1016/j.jss.2009.07.009.
[29] S. Asnaes, F. Paaske, The significance of medicolegal autopsy in determining mode and cause of death, Forensic Sci. Int. 14 (1) (1979) 23–40. http://dx.doi.org/10.1016/0379-0738(79)90152-X.
[30] G.C. Alfsen, J. Maehlen, The value of autopsies for determining the cause of death, Tidsskr. Nor. Laegeforen. 24 (132) (2012) 147–151. http://dx.doi.org/10.4045/tidsskr.11.0427.
[31] Council of Europe Committee of Ministers, Recommendation of the Committee of Ministers to Member States on the Harmonization of medico-legal autopsy rules, European Union, 1999 Report No.: R (99) 3, http://www.coe.int/t/dg3/health-bioethic/texts_and_documents/RecR(99)3.pdf.

[32] Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council, Fragmented and inconsistent medicolegal death investigation, in: Strengthening Forensic Science in the United States: A Path Forward, National Academies Press, USA, 2009, , pp. 49–50Report No.: 228091, https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf.
[33] T. Waldhoer, A. Berzlanovich, C. Vutuc, G. Haidinger, Rates of postmortem examination in Austria: the effect of distance between location of death and site of examination, J. Clin. Epidemiol. 56 (9) (2003) 891–895. http://dx.doi.org/10.1016/S0895-4356(03)00076-3.
[34] B.B. Ong, N. Milne, Quality assurance in forensic pathology, Malays. J. Pathol. 31 (1) (2009) 17–22.
[35] M.A. Clark, The value of the hospital autopsy. Is it worth the cost? Am. J. Forensic Med. Pathol. 2 (3) (1981) 231–237.
[36] A. Sawaguchi, T. Sawaguchi, T. Fujita, R. Matoba, W. Sturner, Research for improving the autopsy rate for infant death - medical economic assessment of the forensic autopsy system in Japan, Forensic Sci. Int. 14 (130) (2002) S91–S95. http://dx.doi.org/10.1016/S0379-0738(02)00147-0.
[37] F.A. Herbella, P.H. Fernandes, C. Delmonte, J.C. Del Grande, Forensic autopsy costs in the city of Sao Paulo, Sao Paulo Med. J. 5 (121) (2003) 139–142.