

Do Centenarians Die Healthy? An Autopsy Study

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Background. Our goal was to assess the prevalence of common causes of death and the demographic variables in a selected population of centenarians.

Methods. The autopsy reports and medical histories of all individuals ≥ 100 years, dying unexpectedly out of hospital, were gathered from 42,398 consecutive autopsies, performed over a period of 18 years at the Institute of Forensic Medicine, Vienna. These records were evaluated with regard to age and sex, circumstances of death, season, time and the cause of death, as well as the presence of any other comorbidity.

Results. Forty centenarians (11 men, 29 women) were identified with a median age of 102 ± 2.0 (range: 100–108) years. Sixty percent were described as having been healthy before death. However, an acute organic failure causing death was found in 100%, including cardiovascular diseases in 68%, respiratory illnesses in 25%, gastrointestinal disorders in 5%, and cerebrovascular disease in 2%. Additionally, centenarians suffered from several comorbidities (cardiac antecedents, neurologic disorders, liver diseases, cholelithiasis), which were not judged to be the cause of death.

Conclusions. Centenarians, though perceived to have been healthy just prior to death, succumbed to diseases in 100% of the cases examined. They did not die merely “of old age.” The 100% post mortem diagnosis of death as a result of acute organic failure justifies autopsy as a legal requirement for this clinically difficult age group.

ALTHOUGH living past the age of 100 is not a new phenomenon, it was much rarer in the past. In industrialized countries, the number of centenarians is increasing at a rapid rate of about 8% per year (1), whereas world-wide population is growing at a rate of 1% per year (2). In Austria for instance, four centenarians were registered in 1950, and 380 in 2001; demographers estimate there will be 503 in 2007 (3). This increase is mostly attributable to enormous advances in medicine, which have helped patients to survive previously lethal acute events and have markedly delayed the course of chronic diseases. In everyday medicine, the biologic age rather than the actual age has become the determining factor for making therapeutic decisions. Thus precise knowledge of the underlying diseases affecting centenarians is urgently needed. Autopsy data are considered crucial for ensuring the quality of medical care (4), and may help to improve our knowledge of the prevalence of diseases in the aged population (5).

Today, economic, legal, and attitudinal issues have led to a significantly reduced autopsy rate, resulting in a conspicuous paucity of available autopsy-proven data. Only a few reports have concentrated on autopsy findings in the 10th decade of life (6–10). Additionally, reported post-mortem observations have been restricted to a very limited number of individuals dying in hospitals (6,11).

In contrast, the Austrian Health Care Acts enable—even demand—that an autopsy be performed by forensic pathologists to certify the cause of death whenever there is no obvious disease to account for it. Thus, the large autopsy rate at the Institute of Forensic Medicine, University of

Vienna, offered a unique opportunity to review a series of 42,398 consecutive autopsies performed over a period of 18 years. This descriptive study analyzing post-mortem findings in centenarians who died out of hospital from natural causes was designed to increase available pathologic-anatomic data on the oldest of the old.

METHODS

Included in this retrospective study were nonhospitalized centenarians who fulfilled the working definition of having a sudden natural death (unexpected or unexplained deaths of nonhospitalized individuals ≥ 100 years which were without obvious cause of death or prevailing diseases).

All nonhospitalized individuals dying of a sudden natural death were gathered out of 42,398 autopsies, consecutively performed at the Institute of Forensic Medicine, Vienna. The autopsy reports and medical histories of the individuals were evaluated with regard to age and sex of the deceased, to the circumstances of death, the season, the time and the cause of death, as well as the presence of any other comorbidity. All autopsies were done by eight physicians specialized in forensic medicine. The mortality registrar of Vienna provided the entire number and sex of centenarians that died during the period 1985–2002 (3).

RESULTS

Incidence, Age, and Sex

According to the mortality registrar of Vienna, 842 individuals ≥ 100 years died in Vienna between 1985 and 2002, giving an average of 6.8 cases per 100,000

Table 1. Medical History of 40 Centenarians Dying Out of Hospital

Preexisting Conditions of the Deceased	Men	Women	Total (%)
Cardiovascular diseases	11	12	23 (58)
Chronic heart failure	5	7	12 (30)
Angina pectoris	3	3	6 (15)
Old myocardial infarction	2	2	4 (10)
Pacemaker implant	1	0	1 (3)
Hypertension	3	6	9 (23)
Diabetes mellitus	1	3	4 (10)
Respiratory diseases	3	1	4 (10)
Gastrointestinal disorders	2	0	2 (5)
Neurological disorders	5	12	17 (43)
Alzheimer's disease	2	6	8 (20)
Parkinsonism	2	3	5 (13)
Hemorrhagic stroke	1	3	4 (10)
Rheumatic disorders	3	1	4 (10)

(CI: 6.3–7.3). Forty (4.8%) of these 842 deceased centenarians died out of hospital and underwent autopsy at the institute. There was a predominance of women (29 women vs 11 men), constituting a ratio of 2.6:1. The median age (\pm standard deviation) was 102 ± 2.0 (range: 100–108) years.

Circumstances of Death

In all cases, sudden death occurred in private homes. Resuscitation was attempted in 57% of these centenarians. Twenty-nine individuals lived unaccompanied in their homes, 14 of them without any care and 15 with regular care by neighbors, relatives, or welfare workers. Eleven centenarians lived with at least one family member. All centenarians were widowed.

Season and Time of Death

Sudden death in centenarians was distributed nearly equally throughout the year, with only slightly more deaths during 3 months (May, June, and July). The time of death peaked between 7:00 AM and 9:00 AM.

Physical Findings

In the 11 men, body weights ranged from 45 to 72 kg (60 ± 10.9 kg), and heights ranged from 151 to 184 cm (167 ± 9.1 cm). Their mean body mass index was 21.5 ± 3.6 kg/m² (range: 16.3 to 25.8 kg/m²). In the 29 women, body weights ranged from 32 to 77 kg (52 ± 10.7 kg), and heights ranged from 139 to 157 cm (149 ± 5.4 cm). Their mean body mass index ranged from 14.6 to 32.9 kg/m² (22.8 ± 4.6 kg/m²). A total of 18% ($n = 2$) of the men and 38% ($n = 11$) of the women had a body mass index exceeding the normal range, whereas 36% ($n = 4$) of the men and 21% ($n = 6$) of the women had a body mass index below the normal range (<20 kg/m² in men and <19 kg/m² in women).

Medical History

Sixty percent ($n = 24$) of the deceased were described by their family or their family physician as having been healthy at the time of death. However, 58% had cardiac antecedents such as chronic heart failure, stable angina pectoris, a history

of myocardial infarction, or an implanted pacemaker. In the remaining individuals, preexisting conditions included hypertension (23%), diabetes mellitus (10%), respiratory diseases (10%), and gastrointestinal diseases (5%). Neurologic disorders such as Alzheimer's disease, Parkinsonism, or hemorrhagic stroke were present in 43% (Table 1). Advanced neoplastic disease with widespread distant metastases was found in three corpses. In only one person of this cohort, the malignancy had been diagnosed during the lifetime.

Autopsy Findings

Causes of death.—Cardiovascular diseases accounted for 68% of the deaths ($n = 27$). Acute cardiac failure from old myocardial infarctions or chronic lesions such as fibrosis or scars were the cause of death in 2 of 11 men and in 4 of 29 women and presented with signs of acute ischemia, acute dilatation, and marked pulmonary congestion. Four men and 11 women had acute myocardial infarction. One woman suffered from an acute dissection of the ascending thoracic aorta with subsequent pericardial tamponade, and in one woman an atherosclerotic fusiform aneurysm of the descending thoracic aorta ruptured. One man and three women died from ruptured abdominal aortic aneurysms.

Six cases of sudden death were caused by pulmonary embolism emerging two times from the right and four times from the left femoral veins. Associated parenchymal infarction was found in one woman. Four centenarians died of bacterial pneumonia; the organisms identified were *Klebsiella pneumoniae* and *Staphylococcus aureus*. A gastric ulcer caused perforation with acute diffuse peritonitis in one 106-year-old man and in one 100-year-old woman. There was one case of subarachnoid bleeding following the rupture of a congenital aneurysm in the anterior communicating artery of the circulus arteriosus. Principal causes of death in centenarians are detailed and compared with causes of death in patients aged ≥ 85 years in Table 2.

Comorbidities.—Autopsy findings revealed the following chronic diseases and preexisting conditions, but they were not the principal causes of death (Table 3). The characteristic external appearance of the senescent heart frequently included brown atrophy, tortuous epicardial coronary arteries, enlarged atria, and small ventricular chambers with a dilated ascending and descending thoracic aorta. Of the four major (left main, left anterior descending, left circumflex, and right) epicardial coronary arteries, 27% had significant occlusive disease (39% of them in the left anterior descending artery) with a reduction in the cross-sectional luminal area of more than 75%. Calcification of atherosclerotic plaques was a constant finding. In 24 of 27 (88%) of patients with a cardiovascular cause of death, calcified atherosclerotic plaques in at least one coronary artery were evident.

In 80%, calcification of the mitral annulus and of the aortic valves was present; 15% of the calcified valves were anatomically stenotic. All deceased individuals had extensive aortic sclerosis, mainly focused in the abdominal region. In all 40 corpses, the aorta was dilated in its

Table 2. Principal Causes of Death in 40 Centenarians in Comparison to 1886 Patients Aged ≥ 85 Years Dying Out of Hospital, Categorized by Organ Systems

Cause of Death	Centenarians			Patients Aged ≥ 85 Years		
	Men	Women	Total (%)	Men	Women	Total (%)
Cardiovascular diseases	7	20	27 (68)	440	1025	1465 (78)
Acute ischemia or myocardial infarction	4	11	15 (38)	250	515	765 (41)
Acute cardiac failure from old myocardial infarctions or chronic lesions	2	4	6 (15)	168	483	651 (35)
Myocarditis, endocarditis	0	0	0	4	5	9 (0)
Aortic dissection or rupture of an aortic aneurysm	1	5	6 (15)	18	22	40 (2)
Respiratory diseases	3	7	10 (25)	63	183	246 (13)
Pulmonary embolism	2	4	6 (15)	26	120	146 (8)
Pneumonia	1	3	4 (10)	32	59	91 (5)
Others	0	0	0	5	4	9 (0)
Gastrointestinal diseases	1	1	2 (5)	36	58	94 (5)
Perforation of a gastric ulcer	1	1	2 (5)	2	10	12 (1)
Perforation of a duodenal ulcer	0	0	0	13	11	24 (1)
Carcinoma	0	0	0	12	15	27 (1)
Ileus, volvulus	0	0	0	5	13	18 (1)
Others	0	0	0	4	9	13 (1)
Diseases of the central nervous system	0	1	1 (2)	12	41	53 (3)
Cerebral hemorrhage	0	1	1 (2)	9	21	30 (2)
Ischemic encephalomalacia	0	0	0	1	9	10 (0)
Rupture of a congenital aneurysm	0	0	0	2	9	11 (1)
Meningitis, encephalitis	0	0	0	0	2	2 (0)
Genitourinary disease	0	0	0	10	16	26 (1)
Metabolic disease	0	0	0	0	2	2 (0)

transverse and longitudinal planes, with aneurysm formation in seven cases.

Senile atrophy of the brain was observed in all centenarians, extensive cerebral arterial atherosclerosis was found in four (10%) and mini strokes in only two cases, respectively. Besides edema, emphysema was found in all cases, and bronchitis was noted in three deceased individuals.

Senile atrophy of the liver was evident in all centenarians. In 23% of the individuals, autopsy results indicated a fatty degeneration ($n=6$) or a cirrhosis ($n=3$) of the liver. Seven cases of cholecystolithiasis were discovered at autopsy.

Gastritis was present in five individuals, and formation of colonic diverticula in seven. These had not been diagnosed clinically. Scar formation, chronic pyelonephritis, and arteriosclerosis and arteriolosclerosis of the kidney were common. Macroscopic nodular prostatic hyperplasia was seen in three men. Atrophy of the testis, ovary, and uterus were also common. Recent fractures were not found. Old consolidated and surgically treated bone fractures were seen in seven women.

Major operations included surgery caused by colon cancer ($n=1$), gall bladder diseases ($n=6$), appendicitis

Table 3. Other Diseases and Conditions (Comorbidities) That Were Not the Principal Cause of Death of 40 Centenarians Dying Out of Hospital

Disease or Condition	N (%)
Cardiovascular diseases	
Postinfarction ventricular aneurysm	3 (7)
Aortic valve calcification	12 (30)
Mitral valve calcification	20 (50)
Aortic dilatation	40 (100)
Respiratory diseases	
Chronic obstructive lung disease, emphysema	18 (45)
Pleural effusions	2 (5)
Hepatobiliary diseases	
Fatty degeneration (medium and high) of the liver	6 (15)
Cirrhosis	3 (7)
Cholelithiasis	6 (15)
Gastrointestinal disorders	
Gastritis	5 (12)
Colonic diverticula	7 (17)
Cerebral atherosclerosis	4 (10)
Prostate hyperplasia	3 (27)*
Previous fractures	7 (17)

Note: *Of the 11 men.

($n=6$), and duodenal ulcer ($n=1$). Two men had undergone a resection of the prostate, and 10 women total had undergone abdominal hysterectomy with bilateral salpingo-oophorectomy.

DISCUSSION

Literature addressing the specific topic of autopsies in centenarians is rare and includes predominantly hospitalized or institutionalized individuals of a very limited number (6,12–15). This current Viennese study fills the gap of knowledge concerning the causes of death in centenarians dying at home.

Our major finding is the striking contrast between an autopsy-proven cause of death in 100% and the fact that 60% of the centenarians were described as having been healthy before death by their relatives and even by their physicians. The Viennese results are consistent with Danish and Finnish data on living centenarians (16,17), presenting chronic cardiovascular diseases in 72%. In the Viennese study, 68% of nonhospitalized centenarians died due to cardiovascular diseases, which is in contrast to autopsy reports of hospitalized centenarians dying because of cardiovascular disorders in only 20%–31% (13,18). It is interesting that pulmonary infections caused death in only 10% in the Viennese study, being in contrast to Mac Gee's (13) autopsy investigations of a hospitalized geriatric population, dying predominantly because of respiratory and urinary infections as well as malignancies. Malignancies did not cause any death in the Viennese study population. In these findings, approximately half of the individuals were diagnosed with neurological disorders, and 10% with diabetes mellitus; the percentage of both diseases again do not differ from the Danish and Finnish data on living centenarians (16,17).

Very old people usually are assumed to be slender, gaunt, or even cachectic (18). However, 79% of the female and 64% of the male corpses in the Viennese study had a normal or even elevated body weight, perhaps reflecting the individuals' general good health. Only patients dying due to pneumonia had a reduced body mass index (19).

Our study population did not suffer from chronic debilitating or bedridden states. This fact is stressed, for example, by the autopsy-proven complete and stable consolidation of any fractures. Women had a higher incidence of fractures, suggesting a higher incidence of osteoporosis (9).

The Viennese study confirms that reaching the age of 100 years is not exclusively reserved for individuals being free from any severe or chronic disease. The centenarians might have been healthier than their birth cohort members who did not reach the age of 100 years. They may have also benefited from disease onset at a later age or from an adaptability enabling them to maintain sufficient biological functions regardless of the presence of several diseases and atrophy of organs.

The distribution and the patterns of causes of death in centenarians—with the exception of respiratory diseases—were nearly similar to the cohort of unexpected out-of-hospital deaths in patients aged ≥ 85 years that have been investigated at our institute (19) (Table 2). Nevertheless, the longevity population seems to have the ability to live with chronic diseases significantly longer than their birth cohort. This ability is associated with specific genetic predispositions (1). Therefore, genetic analyses of centenarians and their long-lived siblings and/or long-lived multigenerational families would help to identify the genes that contribute to human longevity (20,21).

Until recently, advanced age has been considered to be a disease itself (4). However, our study demonstrates that centenarians die as a consequence of organ failures and not because of “old age” as commonly assumed. With some difficulty, physicians have learned to avoid the facile explanation of obscure conditions in very old individuals as being the result of “old age.” Atypical and/or asymptomatic presentations in centenarians are often mistakenly interpreted as an unspecific cause of death (22).

In summary, the majority of centenarians suffered from chronic comorbidities even though they were considered to be healthy. Thus even centenarians should receive an autopsy; their deaths should not be merely attributed to old age or senile debility. The 100% post-mortem diagnosis of acute organic failure causing death justify autopsy as a legal requirement for this clinically difficult age group.

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