Hip fracture in centenarians: Retrospective analysis of an orthogeriatric unit reveals the limitations of the current research

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Abstract
Life expectancy of Italian people is among the highest in the world, at 80 years for males and 85 years for females. Estimates from the National Institute of Statistics show that people aged 65 years and older represent more than 21% of the Italian population. Among them, centenarians represent the age group with the highest growing rate. Hip fracture incidence increases with advancing age, and currently represents one of the major causes of hospitalization in the elderly. Many studies regarding hip fracture in the elderly have been published, but research focusing on centenarians is still very limited despite their growing trend. This manuscript reviews the activity of the Orthogeriatric Unit at San Gerardo University Hospital (Northern Italy) from its establishment in 2007 until the present, and enlightens the limitations of the research in this area reviewing the literature currently available.

Over a 7-year period, we admitted a small population of 10 centenarian female patients, all of whom underwent surgery. Their in-hospital (1 out of 10) and 1-year mortality rates (8 out of 10) are consistent with the existing literature.

Centenarians pose an increasing challenge to physicians and surgeons. Rates of recovery of the pre-fracture condition are undoubtedly lower than those in younger geriatric patients, but surgery and early rehabilitation should not be denied solely due to the extreme age of these subjects. However, the research in this area presents several limitations up to now. The available studies are sparse, describe small populations, and are generally a single-center retrospective review of the local hospital admissions registry. Moreover, the objectives and outcome measurements vary considerably between studies, making a statistical comparison unfeasible.

In this scenario, the implementation and analysis of large-scale databases would allow appropriate research among centenarians, including cost-effectiveness of specific surgical treatments.

Introduction
Life expectancy at birth in Italy is on average 83.1 years (80.2 for men and 85.0 years for women), making this country one of the 10 top-ranked nations in the world for longevity (World Health Organization 2014 report, available at (http://www.who.int/mediacentre/news/releases/2014/world-health-statistics-2014/en/). Italy’s population is one of the oldest in the world, with an expected increase in the proportion of the geriatric population (aged ≥ 65 years) of 20.9% to 21.5% during 2013-2015 (available at http://demo.istat.it). Within this population, individuals aged ≥100 years old represent a particular subgroup. Reaching very advanced age can be considered an example of successful aging, although this homeostasis is frail [1]. Indeed, it is known that the process of aging gradually results in a reduction of the functional capacity of organs. In this age group, referred to as centenarians, the greatly reduced functional organ reserve represents a risk factor for global decline and death, because any stressor can potentially lead to severe organ dysfunction. Fractures and surgical operations are very stressful experiences, and the consequences of such events on a centenarian subject could be devastating [1]. Besides high mortality rates, disability is also a common sequela of major fractures (especially hip fractures) in this age group [2,3].

The Italian National Institute of Statistics (ISTAT, http://www.istat.it/) estimated that the total number of centenarians in Italy was 20,331 individuals in 2014, which is among the highest in Europe (available at http://demo.istat.it), and that they represent the subgroup with the...
highest rate of increase. To date, about half of the Italian centenarians live in Northern Italy, which - along with Central Italy - is also the geographical area with the proportion of over 65 individuals.

Hip fracture (HF) is a frequent occurrence in the elderly, and its incidence grows exponentially as the population ages [4]. A number of studies have already described HF in the elderly, but the available literature focusing on centenarians is limited [2,5-8]. The present manuscript reviews the activity of our Orthogeriatric Unit (OGU) at San Gerardo University Hospital (Northern Italy), which is a reference center for hip fractures in Lombardy region [9,10]. We focused on centenarians admitted from 2007, when the OGU was established, until December, 2014. Our retrospective research prompted us to review the currently available literature, which revealed similar limitations.

**Methods**

**Inclusion and exclusion criteria**

We performed a retrospective review of the OGU activity at San Gerardo University Hospital, analyzing the medical records of all patients aged 100 years and older at the moment of admission, whose principal diagnosis was "hip fracture" or "proximal femur fracture". We identified 10 records of centenarian patients to review.

For the review of the literature currently available, we considered the English language papers published in PubMed online library, combining the key terms 'centenarian' and 'hip fracture', or '100' and 'hip fracture'. We considered only the papers that discussed patients at least 100 years of age, and excluded all manuscripts not written in English. Based on these criteria, we identified 11 papers to review.

The study was approved by the Institutional Review Board of San Gerardo University Hospital.

**Centenarians admitted to the OGU: Review of the activity**

Since its establishment in 2007, the OGU has admitted 10 centenarians, all females. The characteristics of these patients are summarized in Table 1. The patients’ mean age was 100.6 ± 1.0 years (range 100-103 years), while their average length of hospital stay was 14.1 ± 6.0 days. Four of the patients experienced percutaneous fractures, while the remaining six experienced femoral neck fractures. The mean Katz’s ADL score [11] of the study population was 3.1 ± 2.0. Patients’ median Charlson Comorbidity Index [12] was 2.0 (range 1-10). The mean ASA score [12] was 2.9 (range 2-5).

The study was approved by the Institutional Review Board of San Gerardo University Hospital.

**Table 1.** Case series: Demographic data and main characteristics of centenarian patients admitted to San Gerardo University Hospital (Monza, Italy) with a diagnosis of hip fracture, starting from the year of establishment of the Orthogeriatric Unit (2007).

| Patient No. | Age [years] | Gender [M/F] | Year of hospitalization | Pre-fracture residence | Caregiver at home | Katz’s ADL score | Charlson Comorbidity Index | Medications [n] | Preoperative delirium [yes/no] |
|-------------|-------------|--------------|-------------------------|------------------------|------------------|-----------------|--------------------------|----------------|-----------------------------|
| 1           | 100.6       | F            | 2008                    | Home                   | None             | 4               | 10                       | 7              | No                          |
| 2           | 100.0       | F            | 2008                    | Home                   | Family member    | 2               | 5                        | 4              | No                          |
| 3           | 100.0       | F            | 2010                    | Home                   | Family member    | 4               | 1                        | 1              | No                          |
| 4           | 100.0       | F            | 2010                    | Home                   | Family member    | 2               | 4                        | 7              | No                          |
| 5           | 100.0       | F            | 2011                    | Home                   | Family member    | 6               | 2                        | 2              | No                          |
| 6           | 103.0       | F            | 2011                    | Home                   | Family member    | 0               | 3                        | 4              | No                          |
| 7           | 101.0       | F            | 2012                    | Home                   | Family member    | 1               | 0                        | 3              | Yes                         |
| 8           | 100.0       | F            | 2012                    | Home                   | Family member    | 3               | 0                        | 2              | No                          |
| 9           | 100.0       | F            | 2013                    | Home                   | Family member    | 3               | 0                        | 3              | No                          |
| 10          | 100.0       | F            | 2014                    | Home                   | None             | 6               | 1                        | 8              | No                          |

*Activities of Daily Living.*
died during this time frame.

This analysis has limitations. First, in accordance with our aim, this is a single-center retrospective observational study, and therefore the results cannot be generalized. Second, the sample size is small and distributed over a long period (7 years). Despite the retrospective nature of the analyses, which is a common feature of the previous studies, a multicenter design would be desirable to increase the case series and to better analyze the outcomes of this expanding age group.

**Review of the literature**

The first study we found was a retrospective case series analysis of 13 subjects [5]. The study reviewed the local orthopedic activity of centenarians admitted to the Derbyshire Royal Infirmary (UK) between 1988-1999. As the authors expected, the study revealed high mortality rates, especially in-hospital mortality rates (4 cases, accounting for 31% of the study population). The mortality rates increased at 6-month and 1-year follow-ups, reaching 50% and 56%, respectively. However, these results should be examined with consideration of the small sample size.

A second paper, by Oliver and colleagues, [2] compared 18 centenarians with a group of 18 “normal age HF patients”, whose mean age was 78.2 years and who were randomly selected during a 5-year period (1998-2002). They found that 28.6% of the centenarian patients were able to return to their homes, as opposed to a discharge toward a long-term facility, versus 69.2% of the normal age group. Mortality rates were reported to be similar to the study from Forster et al., [5] with an in-hospital mortality of 11.1%, and 1- and 4-month mortality rates of 33.3% and 50%, respectively.

In 2004, a study investigated whether centenarian hip fracture patients really need surgery and rehabilitation [3]. A retrospective case series analysis was performed on 23 patients in an Israeli teaching hospital during a 12-year study period (1990-2001). Nineteen of these subjects underwent surgery, with an average time to surgery of 2.23 days and a mean length of stay of 11.2 days. Mortality rates were reported to be similar to the study from Forster et al., [5] with a discharge toward a long-term facility, versus 69.2% of the normal age group. Mortality rates were reported to be similar to the study from Forster et al., [5] with an in-hospital mortality of 11.1%, and 1- and 4-month mortality rates of 33.3% and 50%, respectively.

In 2009, a manuscript from Kent and colleagues described the results of a retrospective observational database analysis (2004-2005) in a UK hospital in Dorset [15]. The authors focused on 26 trauma admissions in centenarians, 13 of whom were hospitalized for HF. They found in-hospital mortality to reach 19.2%, while 1-month and 1-year mortality rates were 33% and 42%, respectively. They conclude that centenarians should be afforded the same consideration for surgery as younger subjects.

An article from Verma et al., [6] also analyzing the activity of a UK hospital, compared length of stay and time to surgery in centenarians versus younger subjects to investigate whether the oldest patients require additional costs for their treatment. Twenty-six centenarians and 50 elderly patients (mean age >80.5 years) were identified. The mean time to surgery was 3.6 days for centenarians and 1.9 days for the younger ones (non-significant), and the average length of stay was 20.7 days versus 14.9 days, respectively (p=0.0015). In-hospital mortality rate was 17.3% for centenarians vs. 2% for elderly patients, and 1-month mortality rate was 30.4% for centenarians vs. 4.1% for elderly patients. The authors estimate that centenarians undergoing hip fracture surgery require an average additional cost of £2511 (adjusted: £2208).

Referring to the period from 2001 to 2006, Pelavski and colleagues [16] published a retrospective review of activity in a teaching hospital in Barcelona, Spain, focusing on the transfusion practice during hospitalization. They compared 17 centenarian hip fracture patients with 17 “typical age range patients” (mean age >77 years) randomly selected from their database. The significant differences they reported

### Table 2. Case series: Characteristics of fracture, surgical operation, and post-operative period of the centenarian hip fracture patients admitted to San Gerardo University Hospital (Monza, Italy), starting from the year of establishment of the Orthogeriatric Unit (2007).

| Patient No. | ASA score | Type of fracture | Surgical treatment | Anesthesia | Transfusions [n] | Postoperative delirium [yes/no] | LOS [days] | Discharge | In-hospital mortality [yes/no] |
|-------------|-----------|------------------|-------------------|------------|-----------------|-------------------------------|-----------|----------|-------------------------------|
| 1           | 3         | PT               | Screw-plate       | General    | 4               | Yes                           | 11        | Exitus   | no                            |
| 2           | 3         | PT               | Screw-plate       | General    | 2               | Yes                           | 0         | Rehab    | no                            |
| 3           | 3         | PT               | Screw-plate       | General    | 0               | No                            | 15        | Rehab    | no                            |
| 4           | 3         | FN               | Cannulated screws | General    | 1               | No                            | 15        | Rehab    | no                            |
| 5           | 3         | FN               | Hemiarthroplasty   | Spinal     | 2               | Yes                           | 20        | Rehab    | no                            |
| 6           | 4         | FN               | Cannulated screws | General    | 2               | Yes                           | 7         | Rehab    | no                            |
| 7           | 3         | PT               | Screw-plate       | Spinal     | 0               | No                            | 7         | Home     | no                            |
| 8           | 3         | FN               | Gamma nail         | Spinal     | 1               | No                            | 7         | Rehab    | no                            |
| 9           | 2         | PT               | Screw-plate       | Locomregional | 2               | No                           | 22        | Rehab    | no                            |

* Length of stay. Abbreviations: FN: Femoral neck; PT: Pertrochanteric; PNB: Peripheral Nerve block; Rehab: Rehabilitation facility.
were postoperative hemoglobin levels, which were higher for the "typical age range" group, trigger hemoglobin levels, and the incidence of postoperative complications, both of which they found to be higher for centenarians. The in-hospital mortality rate was 11.8% among centenarians, while no cases of death were reported in the typical age range group.

In 2010, a letter from Rodriguez-Molinero and colleagues [7] reported an observational analysis of the Spanish hospitalization database, focusing on centenarians admitted for HF during 2005. They received a total of 162 centenarian HF patients, and found that HF was the leading cause of hospitalization in this segment of the population. In-hospital mortality rate was 17.3%, and the estimated costs related to the care of centenarians, particularly indirect costs, were high. To the best of our knowledge, this is the only study that uses a national database to focus on HF in centenarians.

More recently, Patil et al. [13] published a retrospective review of the 2000-2009 activity of a US hospital in Livingston, New Jersey. The authors described 13 centenarian hip fracture patients, 12 of whom underwent surgery. Five patients (41.7%) were transfused in the perioperative phase. One patient (7.7%) died during hospitalization due to severe pneumonia, which progressed to multisystem organ failure. Two other patients developed sacral decubitus ulcers. According to their database, HF accounted for more than 10% of the hospitalizations among centenarians and 29% of all of the surgeries performed in this age group. They highlight that HF surgery is well tolerated in centenarians, and thus it should be suggested regardless of their extreme age.

Finally, in 2013, Tarity et al. [8] published a retrospective review of the 2003-2010 activity at Thomas Jefferson University Hospital in Philadelphia. The authors described a case series of 23 centenarian patients, 21 of whom underwent hip fracture surgery (mean time to surgery was 0.9 days). Their analysis was oriented towards the long-term follow-up. The patients showed an in-hospital mortality rate of 15%. Cumulative mortality was 20% after 1 month, 30% after 3 months, 45% after 6 months, 60% at the 1-year follow-up, 70% after 2 years, and 90% after 3 years.

Discussion

According with estimates by the ISTAT, the proportion of elderly subjects continues to increase in Italy, and centenarians show the highest rate of increase (estimated +14.5% from 2013 to 2015, available at http://demo.istat.it/uniprev2011/index.html).

HF, one of the most frequent age-related injuries, is an important cause of hospitalization among centenarians [7,13,15]. While the in-hospital mortality is between 7.7%-31%, as reported by the literature, the short- and medium-term mortality rates are particularly high in this group of extreme age [2,5-8,13]. The findings of this retrospective analysis of the centenarians admitted to our OGU are consistent with the existing literature in terms of both in-hospital and 1-year mortality rates. To date, two patients were diagnosed with cancer after hip fracture, and their deaths were a result of these severe comorbid conditions, rather than of complications related to HF itself.

Globally, possible explanations for the high mortality rates seen in centenarians with HF include their remaining lifespan, chronic comorbidity, and functional disability. Chronic comorbidity is a common feature of centenarians, and since it is associated with a very limited organ reserve, it often contributes to the extreme frailty of these patients. Among the oldest old (i.e. people aged ≥85 years), functional disability is common both pre-operatively and as a result of failure in post-operative rehabilitation following hip fracture surgery, and represents a risk factor for poor survival [17,18]. Furthermore, comorbidity and limited organ reserve frequently lead to short-term postoperative complications following emergency surgery, in particular to cardiovascular complications such as hypotension [1]. The common occurrence of delirium and pulmonary complications in centenarians further reflects their frailty status.

However, neither age per se, nor pre-fracture mobility impairment should exclude centenarians from the option to undergo surgery, since their mortality risk is overshadowed by the potential benefits following fixation. Indeed, a few studies report extremely poor clinical outcomes for those patients treated conservatively, in terms of pain, complications, and mortality rate [3,8]. If the rates of recovery are low in terms of pre-fracture walking ability and living status, we must take into account that all of the studies to date have been performed on small samples. When comparing a surgical versus a conservative approach, hip surgery leads to better pain control and early mobilization, which are essential determinants of quality of life. However, a proper analysis of the outcomes of HF surgery and rehabilitation in centenarians, as well as its cost-effectiveness, is currently not achievable due to several limitations.

Limitations

The studies currently available are too sparse and take place over a long period of time. The majority of them describes case series of small sample size and use only a single center, except for one study which described the incidence of HF in the Spanish population using a national on-line database and 162 subjects [7]. In addition, all of the studies adopted a retrospective design. For all of the above reasons, their results cannot be generalized.

Another limitation of the current studies is the heterogeneity of their objectives and methods, including the different time-points adopted for the follow-up appointments. Finally, the research papers rarely include data regarding direct costs sustained for the hospitalization and procedures.

This research area would be improved by expanding the size of the study populations, possibly by implementing regional or national hip fracture databases. Data collection should be designed in a prospective fashion, pursuing uniformity of the in-hospital and follow-up outcome measures.

In a period of financial crisis, inclusion of the calculation of direct costs would allow critical analyses of cost-effectiveness focused on hospital admissions in centenarians, especially for those undergoing surgical procedures such as hip fracture surgery.

Multicenter national and international data exchange will allow for proper future research oriented towards risk/benefits of the hospital procedures, cost-effectiveness, and quality of life optimization in centenarians.

Conclusion

Despite centenarians representing a small proportion of the elderly patients requiring hospitalization, they are the age group with the fastest estimated growth. Consequently, the prevalence of centenarians' hospital admissions and the absolute number of hip fractures seen in hospitals will increase. This will pose a significant challenge to physicians and surgeons, who will need to focus more and more on quality of life in a population with limited remaining lifespan. Although a complete
recovery of the pre-fracture functional status is undoubtedly difficult among centenarians, early surgical fixation and mobilization should still be recommended for the preservation of quality of life, and to potentially increase the rates of restoration of pre-fracture living and ambulatory status. At present, a shift from the “single specialty” care toward a multidisciplinary management is necessary in this extreme age group and in the elderly in general. Finally, in line with the need of large-scale datasets, we are developing a collaboration with the Lombardy Region to realize a study that will enlighten the real-world burden of hip fracture in centenarians through the National Healthcare Utilization database.

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