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# Trends of the Florida Manatee (*Trichechus manatus latirostris*) Rehabilitation Outcomes 1991 - 2017

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## Abstract

A review of medical records from 401 West Indian manatees (*Trichechus manatus latirostris*) presented for rehabilitation from August 1991 through October 2017 was conducted. Outcome data shows an improvement in survivability with the release rate approaching 70% and a significant decrease in hospitalization time from over 250 days to approximate 150 days for all causes of admissions during the last seven years of this review. These improvements in care occurred despite rising rates of admissions into rehabilitation, especially for high-risk patients suffering from watercraft collisions. Causes for this improvement can be complex to derive in a rehabilitation setting but advances in medical management may have a positive effect on rehabilitating Florida manatees in a shorter period.

***Keywords:*** *Florida Manatee; Trichechus manatus latirostris; Wildlife Rehabilitation; Mortality*

## Abbreviations

FWS: United States Fish and Wildlife Service; FWC: Florida Freshwater Fish and Wildlife Commission; SAS: Statistical Analysis System Software; ZT: Zoo Tampa

## Introduction

In addition to watercraft-related deaths and potential loss of warm water refuges [1], drowning due to canal locks and flood gates, entanglement in fishing gear, cold exposure, red tide outbreaks, and habitat loss have all contributed to manatee morbidity and mortality and necessitated manatee rescues. The Marine Mammal Protection Act of 1972 [2], Endangered Species Act of 1973 [3], and the Florida Manatee Sanctuary Act of 1978 [4] prohibit any killing, capture, or inhumane harassment of manatees. The West Indian Manatee Recovery Plan [5] was implemented in March 1980 and provided a framework to provide protection of this species. These policies have resulted in a steady climb in the manatee population. In 1991, there were an estimated 1,267 Florida manatees, whereas in early 2017 the population was estimated at 6,620 [6]. As of March 30, 2017, the endangered status of the West Indian manatee has been changed to "Threatened" by the United States Fish and Wildlife Service (FWS) under the Endangered Species Act [7]. This change does not affect other federal and state protections afforded manatees. Manatee population estimates since have been as high as 10,280 individuals [8].

The four manatee management units in Florida as defined by the Florida Freshwater Fish and Wildlife Commission (FWC) include the Upper St. John's River with an estimated 4% of the manatee population, the Atlantic Coast with 46% of the population, Southwest Florida with 38% of the population, and Northwest Florida with 12% of the population. Identifying the effectiveness or possible shortcomings of rehabilitation efforts is essential to wildlife species that undergo rehabilitation with the intent for eventual release. This type of review is the foundation for improving release rates, enhancing welfare, and optimizing use of resources. The first phase of this study was to

analyze manatee admittance data at Zoo Tampa and identify trends of admission rates and locations of rescue stratified by cause of admittance, age, sex, geographic area, months and years between January 1991 and October 2017 and previously reported [9]. The outcomes of wildlife rehabilitation fall simply into two categories: survival with release back into the wild, or death either because of the medical conditions or euthanasia due to quality-of-life concerns. On rare occasions FWS will allow a non-releasable manatee to remain in captivity but this outcome is not consistent with the goals of the program and these manatees are discounted in this review. Analyzing significant differences or trends in outcomes provides valuable feedback to rehabilitation care providers in optimizing outcomes and in managing scarce resources.

## Materials and Methods

Zoo Tampa has been rehabilitating injured and distressed Florida manatees since August 1991and is one of four accredited manatee critical care facilities in Florida. This facility has three 16,000-gallon medical pools with false bottom floors for critical care of manatees. These medical pools are inter-connected via channels to a 150,000-gallon pool and a 75,000-gallon pool for convalescent care. These two larger pools have underwater viewing for the public and serve as an educational conduit for manatee care and conservation. Manatees that have obvious injuries or are exhibiting abnormal behaviors such as unusual buoyancy and lethargy are typically reported to the FWC. Manatees determined to need medical assistance by the responding team of biologist are typically captured and transported to one of the four federally permitted rehabilitation centers in Florida. Because qualified, practicing veterinarians are not typically on the rescue site nor are they transporting most manatees, no critical care medical support is provided until arrival at a critical care facility. On arrival at Zoo Tampa, manatees are triaged, baseline data is collected including blood sampling, lifesaving procedures are performed if indicated, and most of the manatees are then hospitalized. Data collection ended in October 2017 when the manatee care center at ZT underwent major renovations. Resident cases were transferred, and no further manatees were admitted. Admission study variables included sex, age class, cause of admittance, and location of rescue. Mortality, release, and days in hospital were also collected and are reviewed here. Admittance categories as well as causes of death are defined by the FWC and include watercraft collisions, natural causes (cold stress, breve toxicosis, anything non-human related), other human causes (entanglement, entrapment, captive born, or other causes) and orphaned calves. Mothers of rescued calves and calves of rescued mothers were included in the appropriate category of the manatee requiring rehabilitation. Rehabilitated orphaned manatees must obtain 200 cm before being qualified for release. Straight length criteria for manatees are utilized to categorize various life stages of manatees by the biologist. Calves are classified as < 235 cm, sub-adults from 235 to 265 cm, and adults > 265 cm [8]. A criterion of 200 cm was chosen for this study as that straight length is the determinant for both rescue and release criteria. Orphaned calves were defined for this study as calves less than 200cm straight length. Any isolated manatee less than 200cm is considered a dependent calf and will be rescued if possible and categorized as an orphan.

In contrast to the manatee management units previously defined, the FWC manatee rescue and carcass salvage program divides Florida into five sections (Figure 1); Northeast (NE), East Coast (EC), Southeast (SE), Southwest (SW), and Northwest (NW). The Crystal River (CR) in Citrus County is geographically within the Northwest region but due to the density of manatees in this area and the growing human population, data is recorded for this area separately.


***Figure 1:*** *Florida fish and wildlife commission rescue and carcass salvage program map of Florida. Red outline - Northwest (NW), Green outline - Northeast (NE), Purple outline - East Coast (EC), Orange outline - Southeast (SE), Black outline - Southwest (SW). Blue Circle - Crystal River (CR). Yellow dot - ZooTampa manatee rehabilitation center location. Map provided by http://viewer.nationalmap.gov/viewer/.*

Relationships between admittance and outcome categories, sex, age class, rescue location, were determined using logistic regression in Statistical Analysis System Software (SAS). Data was clustered into approximately 5-year periods with the first and last period altered to account for the total time of the rehabilitation effort [9].

## Results

The ZT manatee medical database from August of 1991 through October 2017 was reviewed and included a total of 429 manatees. Twenty-eight results were excluded due to incomplete data. Four manatee calves were born in captivity and are included in this data. Results are summarized in table 1-4 and figure 2-4. Some notable points from Table 1 include the relatively lower survival and release rates of orphan calves (57%) compared to other admission groups. When comparing survivability of adults vs calves (68% vs 65%) it is important to realize that healthy calves will be captured and hospitalized if the dam is the injured manatee. Over the course of the entire study period watercraft collisions carry the lowest survival rate with 52% mortality associated with this admission cause. Figure 2 graphically shows a trend towards a decrease in mortality over the life of the rehabilitation program during the study period.

| | Admitted | Released | Died |
|---|---|---|---|
| **Gender** | | | |
| Male | 184 | 64% | 36% |
| Female | 217 | 70% | 30% |
| **Age** | | | |
| Adult | 315 | 68% | 32% |
| Calf | 86 | 65% | 35% |
| **Admittance Category** | | | |
| Watercraft Collision | 145 | 48% | 52% |
| Natural Causes | 140 | 82% | 18% |
| Orphaned Calf | 51 | 57% | 43% |
| Other Human Causes | 65 | 86% | 14% |
| **Location of Rescue** | | | |
| Northwest | 127 | 67% | 33% |
| Southwest | 215 | 65% | 33% |
| East Coast | 18 | 89% | 11% |
| Northeast | 10 | 90% | 10% |
| Southeast | 6 | 67% | 33% |
| Crystal River | 21 | 57% | 43% |
| Captive Born | 4 | 25% | 75% |
| **Years** | | | |
| 1991-1995 | 15 | 53% | 47% |
| 1996-2000 | 44 | 64% | 36% |
| 2001-2005 | 71 | 56% | 44% |
| 2006-2010 | 97 | 75% | 25% |
| 2011-2017 | 94 | 70% | 30% |

***Table 1:*** *Selected characteristics of admitted manatees from August 1991 through August 2017. Percentage released or died are rounded to whole numbers.*

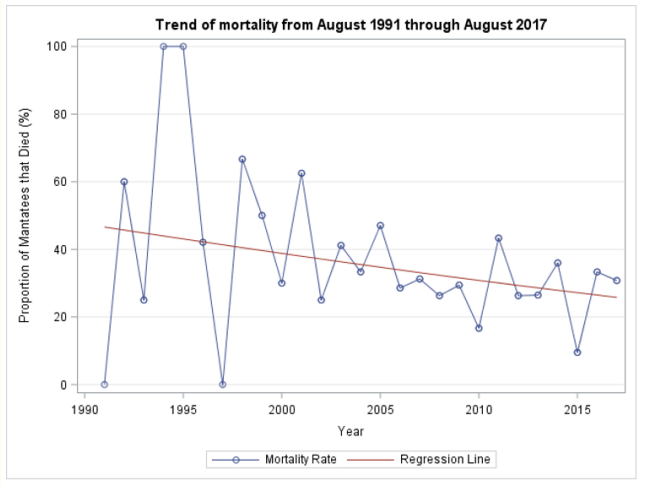


***Figure 2:*** *Mortality (% death/admissions X 100) in each year of the manatee rehabilitation program at ZooTampa. Red regression line is for illustrative purposes only to highlight the downward trend in mortality.*

| Variable | Odds Ratio | 95%CI | | p-value |
|---|---|---|---|---|
| Calf vs. Adult | 0.69 | 0.22 | 2.09 | 0.51 |
| Female vs. Male | 0.76 | 0.47 | 1.23 | 0.27 |
| **Admittance Category** | | | | |
| Orphan vs. Natural | 4.34 | 1.17 | 16.17 | 0.03* |
| Other Human Causes vs. Natural | 0.53 | 0.19 | 1.47 | 0.22 |
| Watercraft vs. Natural | 5.60 | 3.14 | 9.98 | <0.01 |
| **Location of Rescue** | | | | |
| CB vs. SW | 39.99 | 2.89 | 552.75 | 0.01* |
| CR vs. SW | 2.10 | 0.75 | 5.90 | 0.16 |
| EC vs. SW | 0.55 | 0.11 | 2.72 | 0.47 |
| NE vs. SW | 0.29 | 0.03 | 2.71 | 0.28 |
| NW vs. SW | 1.00 | 0.60 | 1.67 | 1.00 |
| SE vs. SW | 0.77 | 0.12 | 4.83 | 0.78 |
| **Years** | | | | |
| 1991-1995 vs. 2011-2017 | 2.31 | 0.66 | 8.05 | 0.19 |
| 1996-2000 vs. 2011-2017 | 1.48 | 0.68 | 3.21 | 0.33 |
| 2001-2005 vs. 2011-2017 | 2.26 | 1.18 | 4.33 | 0.01* |
| 2006-2010 vs. 2011-2017 | 0.73 | 0.39 | 1.38 | 0.34 |

***Table 2:*** *Comparative features of manatee mortality from August 1991 through August 2017 at ZooTampa manatee rehabilitation center. WC= Watercraft Collisions, NC = Natural Causes, NW= Northwest: SW= Southwest; EC= East Coast; NE= Northeast; SE= Southeast; CR= Crystal River; CB= Captive Born. *Indicates significant at P < 0.05.*

In Table 2, the only statistically significant findings are that manatees admitted due to being orphaned showed 4.34 the odds of dying compared to those admitted for natural causes. Manatees that were admitted for watercraft collisions showed 5.60 odds of dying compared to those admitted for watercraft collisions. Manatees admitted between the years of 2001 - 2005 showed 2.26 odds of dying compared with manatees admitted between the years of 2011 - 2017. There were only 4 captive born manatees, thus it would be improper to make inferences based on the collected data and hence the extreme values in the table. Figure 3 and 4 both graphically show another desired trend towards decreased hospitalization time for both released manatees and those that died or were euthanized during rehabilitation.

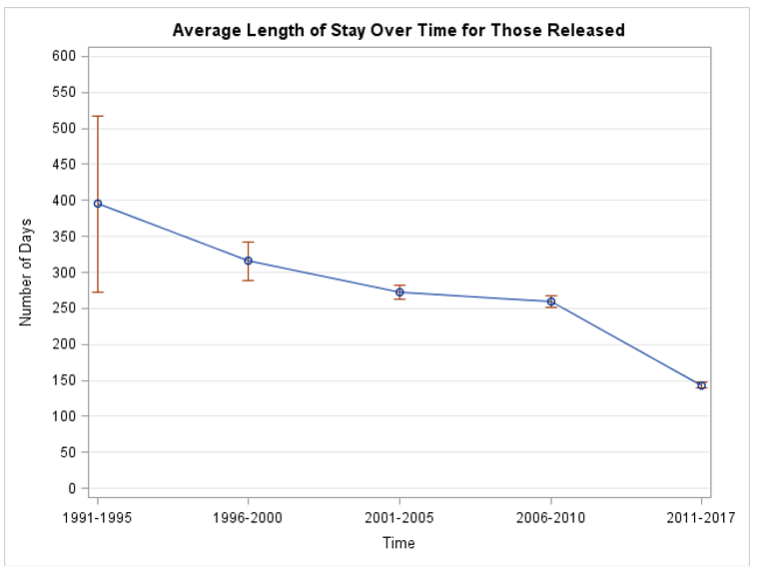


***Figure 3:*** *Average length of hospitalization per time block in calendar years for manatees that were eventually released from the ZooTampa manatee rehabilitation hospital. Red bars indicate standard deviation in the reported averages.*

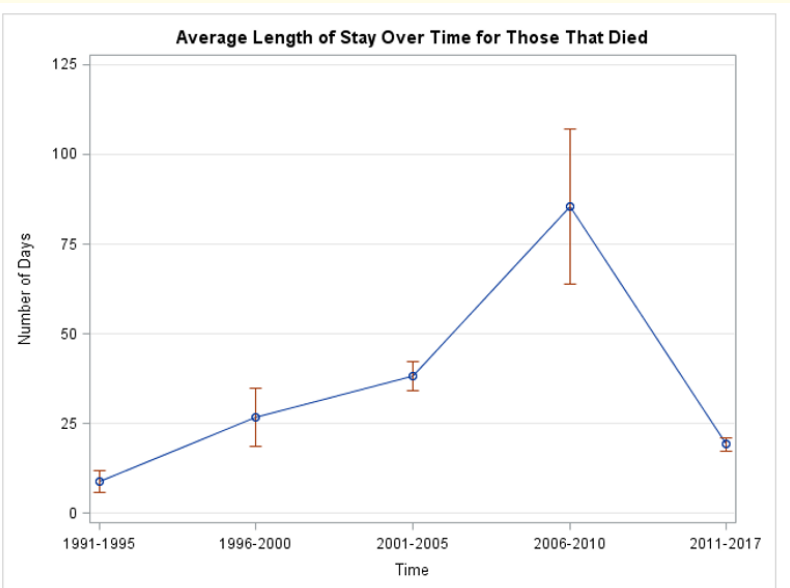


***Figure 4:*** *Average length of hospitalization per time block in calendar years for manatees that died or were euthanized at the ZooTampa manatee rehabilitation hospital. Red bars indicate standard deviation in the reported averages.*

| Variable | Days Additional | 95%CI | p-value |
|---|---|---|---|
| Calf vs. Adult | 74.87 | (-59.26, 209) | 0.28 |
| Female vs. Male | -3.14 | (-67.02, 60.73) | 0.92 |
| **Admittance Category** | | | |
| Orphan vs. Natural | 417.92 | (242.38, 593.46) | <0.01 |
| Other Human Causes vs. Natural | 1.52 | (-89.92, 92.97) | 0.97 |
| Watercraft vs. Natural | 15.96 | (-66.18, 98.09) | 0.7 |
| **Years** | | | |
| 1991-1995 vs. 2011-2017 | 212.12 | (41.45, 382.79) | 0.02 |
| 1996-2000 vs. 2011-2017 | 151.33 | (48.86, 253.8) | <.01 |
| 2001-2005 vs. 2011-2017 | 87.7 | (-5.23, 180.63) | 0.07 |
| 2006-2010 vs. 2011-2017 | 69.06 | (-10.62, 148.73) | 0.09 |

***Table 3:*** *Differences in the length of stays by age, sex, cause of admittance, and time for the subgroup of manatees that were released. Days additional are average days the first group are hospitalized compared to the second group.*

Significant findings in Table 3 include the fact that orphaned manatees on average stayed 418 days longer than manatees admitted for natural causes. Between the years of 1991 - 1995 and 1996 - 2000 manatees that were released stay on average 212 days and 151 days more respectively when compared with manatees admitted between the years of 2011 - 2017. The trend for shorter hospitalization stays continues during the periods of 2001 - 2005 and 2006 - 2010. All these periods are compared to the period 2011 - 2017 which had the shortest hospitalization for manatees that were eventually released (~150 days from Figure 4).

| Variable | Days Additional | 95%CI | p-value |
|---|---|---|---|
| Calf vs. Adult | 7.25 | (-125.67, 140.17) | 0.92 |
| Female vs. Male | -16.17 | (-70.1, 37.77) | 0.56 |
| **Admittance Category** | | | |
| Orphan vs. Natural | -6.89 | (-162.66, 148.88) | 0.93 |
| Other Human Causes vs. Natural | 11.01 | (-117.28, 139.31) | 0.87 |
| Watercraft vs. Natural | 30.19 | (-37.58, 97.96) | 0.38 |
| **Years** | | | |
| 1991-1995 vs. 2011-2017 | -10.53 | (-126.72, 105.67) | 0.86 |
| 1996-2000 vs. 2011-2017 | 12.48 | (-72.37, 97.33) | 0.77 |
| 2001-2005 vs. 2011-2017 | 25.24 | (-46.79, 97.28) | 0.49 |
| 2006-2010 vs. 2011-2017 | 67.04 | (-7.81, 141.89) | 0.08 |

***Table 4:*** *Differences in the length of stays by age, sex, cause of admittance, and time for the subgroup of manatees that died or were euthanized. Days additional are average days the first group are hospitalized compared to the second group.*

While there are no statistically significant differences in the hospitalization time of manatees who died or were euthanized in rehabilitation across the time periods there is a trend towards a shortened number of days hospitalized between the last two time periods of 2006 - 2010 vs. 2011 - 2017 (P = 0.08).

## Discussion

The overall goal of obtaining and analyzing the outcome data was to identify any trends that could be changed to improve outcomes, improve the welfare of manatees during rehabilitation, shorten the period of hospitalization, and optimize resources. Admissions due to watercraft collisions have been rising and are now the leading cause of admissions to ZT manatee hospital [1]. Watercraft collisions also have the highest mortality amongst all the admission categories over the study period with over half of the cases not surviving or being euthanized. Watercraft collisions have 5.6 times the odds of mortality compared to all natural causes combined as evidenced in Table 2. The most serious of these wounds seen at admission involve the dorsum of the manatee and often involve the lungs, which are situated immediately below the spine and ribs. Rib fractures often result in pneumothorax, hemothorax, or pyothorax. A diagnosis of pyothorax, obtained via thoracentesis (Figure 5) typically carries a grave prognosis and often results in euthanasia. An expedient diagnosis in these grave cases can lead to informed decision making and action to improve individual manatee welfare and optimize the rehabilitation process overall.

***Figure 5:*** *Thoracentesis in young manatee. Ethyl chloride is often used to facilitate catheter placement into the thoracic cavity. The presence of thick white fluid is highly suggestive of pyothorax and confirmed with fluid analysis. Continuous suction is applied in this case to treat evacuate the thoracic cavity but almost universally results in euthanasia as in this case. Photo credit: R. Ball.*

Orphan calves also carry a relatively high mortality rate of 43% over this study period. Compared to all natural causes combined, orphans are 4.34 times more likely not to survive (Table 2). Complications with calves often involve nutrition and managing artificial feeding. Gastroenteritis related to bottle feeding is common and expected. Necrotizing colitis and pneumatosis intestinalis are especially dangerous and lead to enterotoxaemia in calves. Simple formulas containing casein and whey protein concentrate with little to no plant fats introduced very slowly have worked the best in the authors opinion.

Hospitalization length for manatees that survived did reach statistical significance when comparing the years 1991 - 1995 and 1996 - 2000 to the most recent period on 2011 - 2017. However only a trend to shorter hospitalization for the periods 2001 - 2005 and 2006 - 2010 compared to the period 2011 - 2017 was demonstrated (Table 3). Despite the lack of statistical significance, Figure 3 clearly shows a decrease of over 100 days hospitalization between the periods 2006 - 2010 and 2011 - 2017. Minimizing the duration of human manage-

ment is an essential component of rehabilitation in any wild species [10]. Habituation to humans is one concern but manatees managed in captivity, either a zoological specimen or in rehabilitation, the captive diet may lead to metabolic alterations that could affect survivability [11]. Diabetes mellitus has been documented in long term captive manatees as well as in rehabilitation settings [12] due to prolonged feeding of romaine lettuce. Shortening hospitalization of course also optimizes resources available for other conservation-based efforts. Efforts during the period 2011-2017 to obtain shorten hospitalization and hence quicker release included utilizing atropine to treat manatees with brevetoxicosis [13], treating open wounds with granulated sugar [14], and nebulization of respiratory infections [15].

There was no statistical significance in hospitalization stay of manatees that either died or were euthanized although a trend is apparent when comparing the period 2006 - 2010 to 2011 - 2017 (Table 4). While statistically not yet significant, clinically this is important in terms of animal welfare as well as optimizing resources when the prognosis is poor or grave. While euthanasia was not specifically measured in this review, the author was the primary clinician during the 2011 - 2017 period and euthanasia for quality-of-life issues was an integral part of manatee rehabilitation program. On occasion manatees with grave prognosis were euthanized perhaps sooner than in the past. This would have shortened some hospitalization times but as can be seen overall did not negatively impact overall successful release rates. It is therefore possible to provide the highest standards of care to individuals with grave conditions while still maintaining and even improving survivability of the manatee hospital patient population as admitted. This is demonstrated in the increased release rates as well as the shorter hospital stays of released manatees seen in this review. All of this was possible even as admission rates increased, especially for causes that carry higher mortality rates such as watercraft admission [9].

## Conclusion

Even in the presence of higher risk manatees at admission and more total admissions, trends of the outcome improved over the course of this study period. An additional observation from this study is the lowered hospitalization time regardless of these increased admission challenges. Efficiencies within the rehabilitation process, application of techniques utilized in other species, and streamlining of the decision making have all contributed to this reduction in hospitalization. Additional recommendations based on medical findings from admissions such as physical examination, hematology and serum biochemistry, and ancillary diagnostics could be evaluated as prognostic indicators and some effort towards this goal has recently been published [16]. Combining outcome results from all the qualified manatee rehabilitation centers could add also highlight any trends point out any potential regional differences in terms of outcomes. Serum lactate has been shown to have prognostic value in survivability in horse with gastrointestinal disease [17] and could be useful in cases of cold stress syndrome. Creatinine kinase could be potentially useful as prognostic biomarkers for survivability with trauma cases. Some reference values exist for healthy captive and wild manatees [18] that could be referenced against manatees admitted into rehabilitation centers. The report from Martony [16] highlights serum calcium, blood urea nitrogen (BUN), platelet count, and aspartate aminotransferase (AST) as analytes that are significantly different in terms of survivability in manatees that have been hospitalized with cold stress syndrome. Continued efforts like these could lead to both enhanced diagnosis and even therapy on site of rescue, reducing or even eliminating some hospital admissions, and providing information for earlier decision-making regarding survivability and indications for euthanasia.

Manatees are also of concern in all parts of their natural range and conservation efforts are in place in various degrees in each location. Brazil has a significant rescue and rehabilitation effort in place and has also reported on the long-term efforts. In the Northeastern Aquatic Mammal Stranding Network's territory of Brazil's Atlantic coast, an average of three Antillean manatees (*Trichechus manatus manatus*) per year have been rescued from 1987 to 2015 for a total of 77 animals [19]. The mean straight length of these alive recused manatees was 136 cm and hence calves. While calves are a significant proportion of manatees rescued in the present study on the Gulf of Mexico coast of Florida, it is vastly different than the scenario described in Brazil. The main threat to this region of Brazil is associated with fisheries and calves becoming stranded [19]. Reviews of admissions [20] and post release monitoring [21] from Brazil report 129 manatees admitted from 1987 to 2015 and a post release survival rate (> 1 year post release) of ~75% but no published information is reported about the mortality after admission to rehabilitation centers.

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