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Commentary and Concepts

Where no guideline has gone before: Retrospective analysis of resuscitation in the 24th century

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ABSTRACT

Aim of the study: Evaluation of the treatment, epidemiology and outcome of cardiac arrest in the television franchise Star Trek.
Methods: Retrospective cohort study of prospective events. Screening of all episodes of Star Trek: The Next Generation, Star Trek: Deep Space Nine and Star Trek: Voyager for cardiac arrest events. Documentation was performed according to the Utstein guidelines for cardiac arrest documentation. All adult, single-person cardiac arrests were included. Patients were excluded if cardiac arrest occurred during mass casualties, if the victims were annihilated by energy weapons or were murdered and nobody besides the assassin could provide first aid. Epidemiological data, treatment and outcome of cardiac arrest victims in the 24th century were studied.
Results: Ninety-six cardiac arrests were included. Twenty-three individuals were female (24%). Cardiac arrest was witnessed in 91 cases (95%), trauma was the leading cause ($n = 38$; 40%). Resuscitation was initiated in 17 cases (18%) and 12 patients (13%) had return of spontaneous circulation. Favorable neurological outcome and long-term survival was documented in nine patients (9%). Technically diagnosed cardiac arrest was associated with higher rates of favorable neurological outcome and long-term survival. Neurological outcome and survival did not depend on cardiac arrest location.
Conclusion: Cardiac arrest remains a critical event in the 24th century. We observed a change of etiology from cardiac toward traumatic origin. Quick access to medical help and new prognostic tools were established to treat cardiac arrest.

1. Introduction

"Space... the final frontier",[1] this quote is well known by science fiction fans all over the world. The television and movie franchise Star Trek has been entertaining millions of viewers all over the globe for almost fifty years. The adventures of starship captains and their crews are set in the 23rd and 24th century, where mankind is able "to explore strange new worlds, to seek out new life and new civilizations" and "to boldly go where no one has gone before".[1] This is accomplished by fictional technologies such as faster than light propulsion, matter-antimatter energy reactors, and many other technical advantages and inventions. Some of these fictional procedures and devices have inspired or anticipated today's technologies. Portable computers, handheld communication devices, or high-speed information networks as seen in the television series have come to reality in today's mobile phones, laptop or tablet computers and the World Wide Web. Other technologies such as matter replication are currently in the very early stages of development.[2] Alongside technological inspirations, *Star Trek* has influenced other aspects of society; the franchise has its popular catchphrases such as "to beam someone up/down" even defined by the Oxford Advanced American Dictionary as "to transport someone to or from a spaceship".[3] Scientific publications took elements of Star Trek as analogy to their research or even investigated the franchise itself.[2,4–6]

The treatment of cardiac arrest has been the subject of many research projects and scientific publications in the 20th and 21st century cumulating in resuscitation guidelines for both laymen and

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professionals.[7,8] Despite many efforts survival rates from cardiac arrest still remain low.[9–11] We were thus seeking inspiration from the future of resuscitation medicine and wanted to evaluate the epidemiology and treatment of cardiac arrest in the 24th century.

2. Methods

2.1. Data source

We reviewed detailed episode guides for all episodes of the television series Star Trek: The Next Generation (TNG), Star Trek: Deep Space Nine (DS9), and Star Trek: Voyager (VOY) on http://en.memory-alpha.org, an Internet database on the topic Star Trek.[12–14] All episodes are spanning a shared 14-year time period from 2364 to 2378. Eligible for inclusion were all adult, single-person cardiac arrests. All bi-pedal, humanoid species were eligible for inclusion. Patients suffering from cardiac arrests were excluded if cardiac arrest occurred during battles or mass-casualties, if the patient died due to complete physical annihilation by energy weapons or physical encasement into solid objects. Patients were also excluded if another individual murdered them and no one besides the murderer was present to provide resuscitation efforts. If a cardiac arrest was described in the episode guide, the event was documented in a screening log for further investigation. The next step was two independent investigators watching all episodes where a cardiac arrest was described. Cardiac arrests matching the exclusion criteria were eliminated. Documentation was performed according to the Utstein standard for cardiac arrest documentation in the 21st century.[15]

2.2. Data

Epidemiological data included the series (TNG, DS9 or VOY), year of cardiac arrest, patient gender, species, professional affiliation (civilian vs. military), rank of military personal, and membership status in a security organization. Cardiac arrest documentation included the location of cardiac arrest. Cardiac arrest on a starship was defined as on-ship arrest and all other arrests as off-ship arrest. Furthermore documentation included the presumed etiology, if bystanders witnessed the cardiac arrest, how cardiac arrest was diagnosed (clinical vs. technically aided diagnosis), if resuscitation efforts were initiated, whether a laymen (basic life support, BLS) or a professional (advanced life support, ALS) performed resuscitation, and what techniques of resuscitation were used (chest compression, defibrillation, medication). Neurological status was assessed using the cerebral performance category (CPC).[15] A CPC score of 1 or 2 was defined as favorable neurological outcome. A CPC score of 3–4 or death was defined as unfavorable neurological outcome. The score was measured at the end of the episode for short-term neurological outcome and at the end of the season for long-term neurological outcome. Short-term survival was defined as surviving the entire episode and long-term survival as surviving the entire season. Ethics approval was not required.

2.3. Statistical analysis

Categorical variables are presented as counts and percentage. Differences between the subgroups were calculated using Chi-square tests. A p-value lower than 0.05 was considered statistically significant.

Data were handled with Microsoft Excel 2011 for MAC (Microsoft Corporation® Redmond, USA) and statistical analysis was performed using PASW Statistics 18.0 for MAC (SPSS Inc., Chicago, USA).

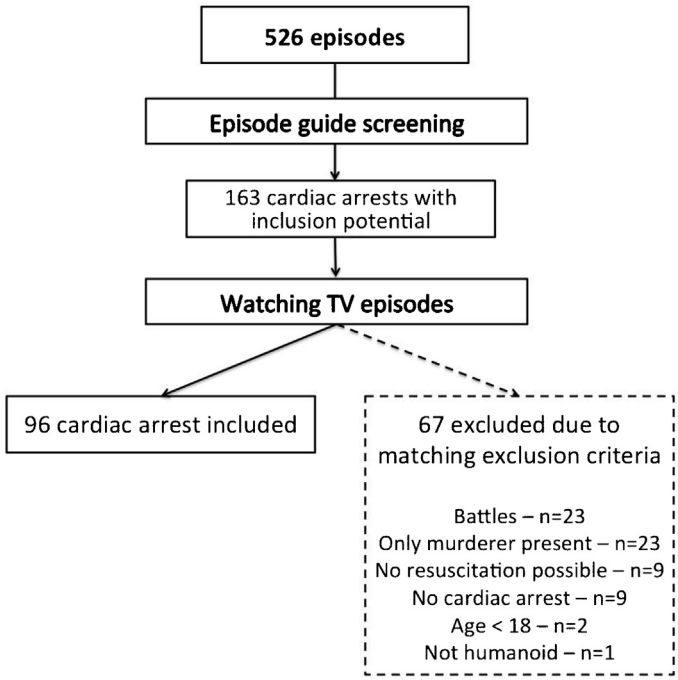

Fig. 1. Flowchart of case selection.

2.4. Role of the funding source

There was no funding for this study.

3. Results

Five hundred and twenty-six episodes were screened for cardiac arrest. The screening process identified 163 cardiac arrest events eligible for inclusion. Sixty-seven of these had to be excluded due to matching the exclusion criteria. Hence 96 cardiac arrests were included and further analyzed. Fig. 1 provides a flow-chart of the patient selection process. Baseline characteristics for all patients can be found in Table 1. Most cardiac arrests occurred in DS9 (n = 36; 38%) followed by VOY (n = 31; 32%) and TNG (n = 29; 30%). Overall cardiac arrest was found mostly in Humans (n = 35; 37%), followed by Klingons (n = 14; 15%) and Bajorans (n = 7; 7%). Twenty-three individuals were of female gender (24%), 45 individuals (47%) were serving in militaristic institutions, including eight members (8%) of security-affiliated organizations. Cardiac arrest was witnessed in 91 cases (95%) and was either diagnosed by clinical examination (e.g. checking for pulse or breathing) in 60 cases

Table 1
Baseline characteristics of all patients – data presented as no./total no. (%).

n	96
Female gender	23/96 (24)
Member of military organization	45/96 (47)
Member of security organization	8/96 (8)
Witnessed cardiac arrest	91/96 (95)
Technically diagnosed cardiac arrest	36/96 (38)
Off-ship cardiac arrest	42/96 (44)
Resuscitation attempted	17/96 (18)
Chest compressions performed	5/96 (5)
Defibrillation performed	1/96 (1)
Medication administered	12/96 (13)
Mild therapeutic hypothermia	0/96 (0)
Good neurological function short term	10/96 (10)
Good neurological function long term	9/96 (9)
Short-term survival	11/96 (12)
Long-term survival	9/96 (9)

Table 2
Causes of cardiac arrest listed alphabetically.

Etiology	No./total no. (%)
Cardiac	3/96 (3)
Electrical discharge	5/96 (5)
Energy weapon	23/96 (24)
Major burns	3/96 (3)
Multi-organ failure	3/96 (3)
Neurological	6/96 (6)
Respiratory	1/96 (1)
Septic	2/96 (2)
Toxic	8/96 (8)
Trauma	38/96 (40)

(63%), or with technological devices (e.g. a device called "Tricorder") in 36 cases (38%). Off-ship cardiac arrest was documented in 42 patients (44%). Trauma was the major cause of cardiac arrest ($n = 38$; 40%), followed by energy weapons (n = 23; 24%) and various toxins ($n = 8$; 8%). Further details are shown in Table 2. Resuscitation efforts were initiated in 17 patients (18%), in 13 patients immediate advanced life support was provided by a physician. In case of attempted resuscitation, drugs were used in 12 cases (13%), chest compression in 5 cases (5%) and cardiac defibrillation in one case (1%). Twelve patients (13%) had return of spontaneous circulation. Short-term neurological function was classified as CPC 1 or 2 in 9 patients (9%). Mild therapeutic hypothermia was used in none of the cases for post-resuscitation care. One patient died early after successful resuscitation (1%) and one patient (1%) was substantially ameliorated in the long-term follow-up. Two patients were lost to long-term follow-up; all other patients had good neurological function ($n = 9$; 9%) and survived the entire season ($n = 9$; 9%). Comparison of on-ship and off-ship cardiac arrests showed no significant difference in terms of resuscitation initiation (10% vs. 7%; $p = 0.81$), long-term favorable neurological outcome (6% vs. 3%; $p = 0.55$) or long-term survival (6% vs. 3%; $p = 0.55$). In case of diagnosis of cardiac arrest by technical devices, resuscitation attempts were initiated more often (12% vs. 6%, $p = 0.01$). Favorable neurological function (9% vs. 1%; $p < 0.01$) and survival rates (9% vs. 1%; $p < 0.01$) were significantly higher in the technical diagnosis group. Affiliation with a security organization was not significantly associated with lower rates of CPR initiation (15% vs. 3%; $p = 0.21$), worse neurological function (7% vs. 2%; $p = 0.12$) or lower survival rates (7% vs. 2%; $p = 0.12$).

4. Discussion

Obviously, despite technical advances, cardiac arrest still remains a critical event in the 24th century. The reason for sudden death shifted from cardiac to traumatic origin. Although nearly all cardiac arrests (91%) were witnessed, resuscitation efforts were initiated in 17 (18%) cases only. This percentage seems quite low compared to contemporary data. [16–18] Nowadays, in the 21st century, traumatic cardiac arrest (TCA) is associated with poor rates of survival (overall 6%) and too little favorable neurological outcome (2%).[19] Resuscitation after penetrating trauma, e.g. by projectiles or stabbing, shows low rates of survival (3%) and low frequency of favorable neurological outcome (2%). [19]

Cardiac arrests caused by energy weapons can be classified as traumatic in origin. According to the Deep Space Nine Technical Manual most energy weapons use some form of concentrated energy in projectile or beam form.[20] Although no solid projectiles are used, energy weapons seem to have a similar effect as today's firearms, leading to extensive tissue damage, burns and blood loss. The omission of desperate resuscitation efforts might be a possible explanation of low rates of resuscitation initiation in the future. Cardiac etiologies as cause of cardiac arrest have become quite seldom compared to today.[16–18] We attribute this to a healthier life style (e.g. rare observation of cigarette smoking) and advances in medicine. Generally speaking, in the 21st century, out-of-hospital cardiac arrest is associated with lower rates of favorable neurological outcome and survival compared to in-hospital cardiac arrest.[21] In our study neurological outcome and survival were not different regarding cardiac arrest location. Matter transportation (so-called "beaming") is one of the crucial 24th century technologies. In the process of beaming, matter is broken down in its molecular components and transported to the target location. There the process is reversed by reassembling the transported object from its molecular components. It allows for quick and convenient transportation within the transporter range, deployment of medical staff to a cardiac arrest victim or transporting patients to a medical facility. The distinction between in-hospital/on-ship and out-of-hospital/off-ship cardiac arrest no longer seems valid in the 24th century. All cardiac arrest victims can be assessed immediately for life support this way. Cardiac arrest can be diagnosed by clinical examination (e.g. seeking signs of life such as pulse or regular breathing) or by technical devices (e.g. electrocardiogram, continuous arterial blood pressure measurement). In our study about one-third of all cardiac arrests were diagnosed by technical devices such as scanners or hand-held devices, called tricorders. The medical tricorder is equipped with 315 mounted sensor units, a detachable hand scanning unit, multiple touch input fields and a display in a gamma-strengthened polyduranide casing.[20] It combines the possibilities of measuring vital signs, organic function, laboratory parameters and imaging studies in a single, portable device. By examining all the aspects of the current body functions and the underlying patho-mechanisms, tricorders and medical scanners seem to provide not only information on the current medical condition but also on outcome prognosis. This might explain why resuscitation efforts are initiated significantly more often in technically diagnosed cardiac arrest and why these patients survive longer and with good neurological function. It seems that technical devices identify promising patients, as they provide quick and extensive information on the current patient status. Toxic cardiac arrest was found in nine patients. Future space travel seems to be associated with high risk of intoxications. A study by Chyka and Banner already investigated this topic for the 23rd century. They described a wide variety of toxins, mostly bio- or neurotoxins, with potential for deadly intoxications. [6] We found that today's resuscitation techniques were mostly replaced. Only one patient was shocked with a defibrillator. No patient was intubated. Laymen administered rescue breaths and chest compressions in two cases only, and only three patients received chest compressions by a physician. The tradition of poorly portrayed resuscitation efforts in television is sadly continued in the Star Trek franchise.[22] However we could not find any resuscitation guidelines for the 24th century. According to the Starfleet Medical Handbook from the 23rd century chest compressions and ventilations should be performed with a 5:1 ratio at a rate of 60 compressions per minute. In intubated patients the ratio changes to 15:2 at a rate of 85 compressions per minute. There is no mention of defibrillation.[23] Resuscitating extra-terrestrial life forms is associated with pitfalls.[24] Chest compressions seem to be a reasonable technique of resuscitation, even in non-human cardiac arrest victims. In Star Trek all humanoid life in the galaxy is originating from a common predecessor species with similar anatomical specifications.[25] As illustrated by the Starfleet Medical Handbook most species possess the anatomical equivalents of a rib cage, protecting lungs and heart with similar anatomical properties to human anatomy, making the principle of chest compressions and rescue breaths feasible.[23] Nevertheless, we observed that chest compressions were performed rarely and not very close to the guidelines of the 23rd century. Twelve patients received

medication during resuscitation by needle-less, transdermal injection. The most common drug was a substance called cordrazine. It was administered in six cases. It is known to increase myocardial contraction and to revive nerve impulse transmission in the brain.[23] Nowadays, transdermal injectors are already in use but mainly for vaccination or insulin administration.[26,27] Mild therapeutic hypothermia seems to have been refined to hibernation in post-resuscitation care. We observed two cases of the so-called "stasis therapy", resembling a medically induced hibernation, which lowers oxygen consumption and acts cerebro-protective.[28] First steps have already been taken in this direction in our days, as Behringer et al. showed good neurological function in dogs after 60–120 min of cardiac arrest by rapid induction of profound hypothermia.[29] A well-known event in the Star Trek Franchise is the so-called Red-Shirt Phenomenon. It originates from the classic Star Trek series of the 1970s and describes the appearance of a nameless crew member, who is wearing a red uniform and gets killed instantly. Red shirts were members of the security forces in the classic Star Trek series. We could not find a difference in terms of resuscitation initiation, survival rates or incidence of good neurological outcome between security officers and non-security officers. This seems contradictive to the Red-Shirt Phenomenon, but can be explained by the inclusion criteria of our study. We only included single person cardiac arrests and excluded all battle-associated cardiac arrests. According to the exclusion criteria, many cardiac arrests of security officers (Red-Shirts) had to be excluded, as they occurred during mass casualties or battles. Therefore, this study could not show the Red-Shirt Phenomenon.

We had some discussion about the retro- or prospective nature of our study. As all cardiac arrests were documented on film, a retrospective analysis of future events was performed, with the intention to improve cardiac arrest treatment. Data have been screened carefully, but it remains unclear whether all cardiac arrests have been documented in the episode guide. All cardiac arrests were documented with great care to avoid data error or misinterpretation by two independent investigators.

5. Conclusion

Cardiac arrest in the 24th century remains a critical event and is mostly caused by trauma. Technical inventions will improve advanced life support and reduce time from collapse to start of resuscitation efforts. The medical tricorder and medical scanning devices seem to provide information on current condition and prognosis of the patient, helping to identify promising patients. Despite over 300 years of medical developments survival rates remain low, although the cause of cardiac arrest has shifted from cardiac to traumatic origin. Quicker access to medical professionals and new prognostic tools or markers should be in the focus of future resuscitation medicine, so that our patients shall "live long and prosper".

Conflict of interest statement

None of the authors have to declare a conflict of interest.

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None.

Author's contribution

DH is fanatical about Star Trek and had the idea for the initial manuscript after reading a paper on traumatic brain injury in the Asterix comics.[30] DH and JH performed the screening process and cardiac arrest documentation. HB, NG, AS, CT, CW and FS were amused by the concept and thus provided background information, further input and analysis. MH critically revised the manuscript, supervised the project and asked many non-Star Trek questions.

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