Construction of Medical Care System for manned mission to Mars

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ABSTRACT

Over 40 years ago man put his foot on the Moon, setting thereby a further goal to achieve – manned mission to Mars. Scientists of various disciplines and almost all countries of the world work on countless aspects associated with such an ambitious task. The aim of this article is to summarize tasks that have to be solved in order to create Mars Medical Care System (MMCS). Analyzing literature in this task, the problems are the underlined and then a possible algorithm for solving them is proposed.

INTRODUCTION

From time immemorial, philosophical questions of who we are and what we are heading for were a trigger to deal with white spots on a map of knowledge. At the beginning great explorers, like Columbus, Magellan or Amundsen, discovered the uncharted corners of the globe. Over 40 years ago a man put his foot on the Moon, setting thereby further goal to achieve – manned mission to Mars. Alongside with technology development, such a mission becomes real. Scientists of various disciplines and almost all countries of the world work on countless aspects associated with such an ambitious task. Recently Kozicki et al published a project of easy-to-build Mars Base, which shows there is an interest in the issue in Poland as well (1,2). However, there is a bigger problem that needs to be solved, beyond technical aspects of landing on Mars, namely, establishment of health care system able to secure the crew and increase the probability of the mission to be successful.

The aim of this article is to summarize tasks that have to be solved in order to create Mars Medical Care System (MMCS). Health care systems as-
associated with spaceflights were developed mainly thanks to NASA expeditions and long-term stays of cosmonauts in orbital stations – MIR and, currently, International Space Station. Experience gathered during circumterrestrial flights let divide the space-flight health care system into five stages (3). Health care in circumterrestrial orbital station or – in future – Moon base focuses mainly on maintaining Basic Life Support and Advanced Life Support, which enables immediate return of ill crew member back to Earth to receive final medical care.

However, the journey to Mars and stay in the habitat of Red Planet requires new – completely different – approach crew members health care. The return to medical center on Earth would not be possible, so health care system must warrant not only life support but also has to enable diagnosing and starting appropriate treatment. Obviously, the need to fit all the equipment in one spaceship significantly impedes the development of Mars Medical Care System. MMCS should be created in the smallest possible volume. It is considered, that priorities of the mission are survival of the ship, the health and safety of the crew, mission success, and profitability of the project.

Since the governments of developed countries, as well as research centers, intend large financial and scientific outlays for space projects, more and more focused on a manned mission to Mars, it seems essential to develop similar studies in Poland. It is important also because it may allow Polish scientists working on this issue (1,2) remain in the country. The scale of the anticipated project – the construction of a fully functional model of the Mars research station in 1:1 scale – gives great potential of scientific research and development, starting from material technology, going through life support systems, integrated communications systems with mission control center, research stations, and ending with assessing the possibility of diagnosis and treatment on a distant planet.

The conditions of Mars environment and the journey itself are quite different than those prevailing on Earth, which has a determinant influence on crew members health and success of the whole mission.

Conditions affecting the crew members are: low temperature (-100 to -30°C), low atmospheric pressure (5 hPa), toxic atmosphere (95% CO2), low gravity conditions (30% of the Earth – microgravity), cosmic rays (Galactic Cosmic Radiation, Solar Partical Events and High Energy Heavy Ion Particles) much less absorbed by the thin atmosphere layer and lack of a protective magnetic field, chemically active dust on the surface of Mars, the impact of solar flares, mutations of terrestrial microbes exposed to microgravity and cosmic radiation or finally, different aesthetics resulting from the construction of the surface of Mars (lack of flora, different color of the sky).

These conditions affect many elements of health and homeostasis, leading to:

- impairment of the human immune system in the area of microgravity (5),
- reduction in red cell mass,
- impairment of the bone structure by increased demineralization, which may increase the risk of:
  - nephrolithiasis,
  - bone fractures,
  - treatment resistant osteoporosis,
- atrophy and strength impairment of muscles,
- central nervous system disorders (6),
- cardio-vascular disorders,
- increased risk of tumor development – in particular tumors of the lymphatic system (lymphomas and leukemias), gonadal tumors, breast cancer, skin cancer, cancer of the gastrointestinal tract,
- thermoregulation disorders,
- quick exchange of the bacterial flora in a closed environment among the crewmembers (7),
- lack of data on the presence of local microbes,
- sleep disorders, which may also increase the already high levels of stress in a foreign environment,
- increasing of the stress of isolation, monotony of meals, and problems in interpersonal communication with other crewmembers,
- possible lung damage resulting from hypoxia and radiation exposure (8).

Besides, while planning the health care system, some important issues should be taken into account:

- The system should also work during the trip to and from Mars (approximately 120 - 180 days).
- Using ground support will be greatly hampered due to delay in communication ranging from 7 to as much as 40 minutes.
- There is a possibility of lack of communication for about 30 days due to the motion of the planets.
- The length of stay on Mars is about 500 to 600 days.
- There should exist a plan of an appropriate quarantine process for the crew returning from a mission in order to prevent any seepage of mutant microbes to the terrestrial environment.

The MMCS will focus primarily on the prevention and will start operating at the stage of planning the mission on Earth. It will be divided into three important components:

1. Primary prevention – proper selection of the crew members before the mission, which warrants a minimum risk of diseases of affluence such as acute coronary syndrome and cancer.
2. Secondary prevention – involving a constant screening of the crew members throughout the mission which will enable early detection of potential
problems that have not yet led to clinical presentation, as well as carrying out appropriate training and security algorithms that reduce the risk of injuries or cosmic radiation exposure.

3. Treatment – initially basic life support of the crew member, then procedures leading to diagnosis and appropriate treatment, all of which should enable the crewmember to perform his duties during the Mars mission.

With such a division of tasks MMCS qualifies in the highest, fifth degree of health protection created by NASA. Equipment taken on a mission must allow the following tasks: laboratory monitoring of all crew members, basic and advanced life support, advanced cardiovascular life support, advanced trauma life support; microbiological, mycological, virological, and biochemical initial diagnosis, as well as diagnostic imaging, diagnostic endoscopy. Also, advanced telemedical system is needed to provide contact with the base on Earth and enable the use all the medical databases such as www.medtube.net or www.pubmed.com, carrying out simple and specialized surgical procedures, implementing maintenance therapy, rehabilitation or ambulatory care. Events during the mission may be divided into different degrees of danger shown by Table 1 along with possible ways to solve a medical problem.

Such plan of system allows to assess the necessary equipment comprising the MMCS:

1. Furniture
   a. Bed
   b. Closets for medical equipment

2. Basic and advanced life support equipment
   a. Resuscitation set
   b. Respirator
   c. Monitor showing ECG, blood pressure, oxygen saturation, respiratory rate, capnography
   d. Defibrillator
   e. Compressed oxygen and air cylinders

3. Microbiological, mycological, virological and laboratory diagnostic equipment
   a. Combo laboratory set
   b. Microscope – integrated with telemedical equipment

4. Equipment for diagnostic radiology
   a. Portable X-ray machine
   b. Portable ultrasound machine
   c. Intravenous contrast agents

5. Equipment for diagnostic endoscopy
   a. Endoscope, colonoscope, bronchoscope
   b. Endoscopic pliers, needles, loops, electrocoagulation and argon (with the cylinder of argon)

6. Telemedical equipment, enabling consultations and contact with Earth medical databases

- a. Computer integrated with all diagnostic and monitoring systems, connected to Earth base

7. Equipment for surgical operations
   a. Electrocoagulation and harmonic scalpel
   b. Laparoscope + CO2 cylinder
   c. Suspenders, surgical sutures
   d. Scalpels, scissors, hemostats, forceps, Kocher forceps
   e. Swabs, haemostatic sponges
   f. Suction machine, pleural and peritoneal drains
   g. Vascular prostheses
   h. Orthopedic prostheses – Schanz collar, stabilization of the thoracic spine, Dessault bandage, stabilizers of the knees, elbows, ankles, and wrists

8. The equipment and catheters for peritoneal dialysis

9. The equipment allowing sterilization – gas autoclave along with gas cylinder

10. Chamber, suit or decompression ward for baro-trauma treatment

11. Medical equipment and medicines
    a. Intravenous fluids + parenteral nutrition, blood, plasma
    b. Urinary catheters, central venous catheters, equipment for fluids infusion and blood collecting and transfusion
    c. Needles and equipment for the collection of blood and urine samples
    d. Syringes
    e. Bandages, dressings
    f. Liquid disinfectants
    g. Medications:
        • Antibiotics; antifungal and antiviral drugs
        • Anti-inflammatory drugs - NSAIDs and steroids
        • Analgesics and anesthetics
        • Catecholamines and atropine
        • Anti-arrhythmic drugs
        • Gastrointestinal drugs: proton pump inhibitors, spasmyloytic drugs, activated carbon
        • Laryngological and ophthalmic drugs: eye and ear drops, Xylometazolinum, sodium tetraborate
        • LMWH
        • Antihypertensive drugs
        • Drugs and dressings for the treatment of burns

12. Protective equipment – disposable and reusable
    a. Masks, gloves (sterile and non-sterile), protective equipment

13. Gymnastic and rehabilitation hall
    a. Stationary bicycle
    b. Treadmill
c. Dumbbells

Of course, many issues related to the operation of MMCS remain unexplained. The need for a CT scanner is unclear and the question is whether ultrasound and X-ray are able to replace tomographic diagnosis. A tomograph is heavy and requires special radiation protection. Moreover, no one knows how exact would the device be in a habitat influenced by cosmic rays stronger than on Earth. Should the Mars mission have skilled doctor and medical officer in one person or two specialized doctors? The second solution gives equal medical coverage for all members of the crew. A single doctor does not give full protection, especially in the case of any events concerning the doctor himself. It is not clear for how long the equipment should be prepared, considering amount of drugs and intravenous fluids. Another problem is the algorithm for dealing with a member of the crew, whose injury/illness exceeds the capacity of the treatment within the system. Should the remaining team be exposed to possibility of loss of medical supplies?

Experiments in Mars-like habitats or ground simulation of a Mars mission should provide answers to those and similar questions. For example Mars-500 project was a series of long-duration analogue studies conducted between 2007 and 2011 in Russia, with its final stage simulating 520-day manned mission to Mars. The international crew of six volunteers was put in mock spacecraft to provide conditions of extremely long isolation, what made scientific research focused on medical and psychological aspects possible (9). Data, knowledge and experience gathered during the experiment will help plan a real mission to Mars, revealing specific difficulties to cope with. Widely commented concern includes disturbances of sleep quality of the crew that led to lethargy, isolation or even depression (10).

CONCLUSION

Creating reliable Mars Medical Care System is a very difficult task with a demand for multidisciplinary approach, which exceeds capabilities of one country, and therefore an effort of different scientific institutions from different countries as well as governments should be applied to solving the problem.

DISCUSSION

Journey to Mars is certainly a fascinating step on the way to space exploration. Equally fascinating is the idea that Polish studies conducted in the habitat of Polish project can contribute to the solution of many Martian mission problems. The economic crisis should not become an excuse for closing up to new possibilities. What could help is just a little bit of political will – it is well known that investing in research and new technologies is one way of limiting the impact of the crisis on the societies.

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PICTURES AND FIGURES

TAB. 1 Danger degrees and ways to manage medical problems on Mars.

<table>
<thead>
<tr>
<th>Low degree of danger</th>
<th>Infections, minor injuries</th>
<th>Ambulatory care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium degree of danger</td>
<td>Injuries, burns, decompression, abdominal cavity diseases, severe infections, myocardial infarction</td>
<td>Surgical treatment, intensive therapy, and consequently the need for proper wards</td>
</tr>
<tr>
<td>High risk degree of danger</td>
<td>Severe injuries, severe myocardial infarction, sepsis</td>
<td>Life support, surgical treatment, intensive therapy</td>
</tr>
</tbody>
</table>


BIBLIOGRAPHY

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