Radiotherapy under the falling bombs: a tale of two Ukrainian cancer centers

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Conflict of interest: None
Funding: None

Interview videos were translated and subtitled by Natalka Suchowerska and Ruslan Zelinskyi. Natalka Suchowerska and Ruslan Zelinskyi attest that the subtitles are correct to the best of their abilities.

The full-scale Russian invasion of Ukraine on February 24th, 2022 brought the largest humanitarian disaster since the World War II to the heart of Europe. The Russian army has caused absolute destruction and chaos for everyone in its path, and Ukraine has lost tens of thousands of civilian lives, out of which many were innocent children. Many more have been wounded, with approximately a third of the population of Ukraine being displaced: 7 million as refugees and 7.1 million as internally displaced people (1). The Russian army is obliterating Ukrainian cities, targeting critical civilian infrastructure with missiles, deliberately damaging and destroying hospitals and clinics in violation of the Article IV of the Geneva Convention (2). According to Ukraine’s Minister of Health, Viktor Lyashko, during the first 100 days of war more than 600 healthcare facilities sustained damage, 105 of which were rendered beyond repair (3). Even if the war stopped today, the damage to the healthcare infrastructure will remain for years to come without world’s continuing support.

Prior to the full-scale Russian invasion, according to unpublished Ukrainian NCI (Tumor Registry) data, in Ukraine with 44 million population, an estimated 139,000 people were living with newly diagnosed cancer, and between 1,000 and 1,200 children were receiving active cancer treatment (AB, unpublished) (4). As to radiotherapy, Ukraine is
classified by DIRAC IAEA as a Low Middle Income country with the level of availability being 2.6 External Beam Radiation Therapy (EBRT) machines per 1 million people (5). Until Russia annexed Crimea and parts of the Donbas region in 2014, Ukraine had 52 radiation therapy centers with 86 Co-60 machines (81%) and 20 linear accelerators (19%) (5). Since 2014 Ukraine has lost control of 10 cancer centers and over 13 EBRT machines in occupied part of Donbas and 5 machines in Crimea (totally 17% of Ukrainian EBRT machines) (6). To address the growing need for cancer treatment, 16 linear accelerators were installed by 2022, and the ratio of Co-60 to linear accelerators became 54% to 46% (without taking into account EBRT machines in the occupied territories since 2014). The Ministry of Health of Ukraine planned to purchase additional 20 linear accelerators, but this plan did not materialize as the Russian full-scale invasion shattered Ukraine in the early hours of February 24th. In the fourth month of the war, the situation in Ukraine is fluid, and as of June 10th, 2022, 3 additional cancer centers are under occupation, 3 cancer centers have suspended operation, and 2 cancer centers are under constant shelling (Fig 1). Some of the centers in the west of Ukraine operate with double the volume of patients.

Ruslan Zelinskyi, the President of the Ukrainian Association of Medical Physicists, and Nataliya Kovalchuk, a Clinical Associate Professor at Stanford, interviewed the radiation oncologists from two radiation oncology centers: Dr. Andrii Hanych, the chair of the Radiation Oncology Department at Mariupol Oncological Dispensary and Dr. Yuliia Severyn, a radiation oncologist at the National Specialized Children’s Hospital OKHMATDYT in Kyiv.

**Mariupol Oncological Dispensary**

Dr. Andrii Hanych: “We were not really prepared for the war. The only provisions we made was for a large quantity of bandages to care for the wounded. After constant attacks on Mariupol, we started to experience the shutdown of electricity. To continue treating our patients, we tried to connect the generator, which proved to be very challenging as the simultaneous gantry rotation with compressor was very power consuming. We eventually stopped treating as the situation in the city deteriorated, and there was nobody to pick-up the dead on the streets. In our hospital, the corpse was stored for 5-6 days. At that point, we decided that we could not continue treating in these conditions. Our foremost goal was to preserve the lives of our patients and to make their stay at our hospital acceptable.”

“At the time when the military action started, we had 12 patients in our care. Those were the patients who had nowhere to go as their homes were either destroyed or were without electricity, water, or gas. We believe we saved the lives of these patients. The most important task for us at the time was to find the potable and technical water. Fortunately, in March it was still snowing, so sufficient technical water could be sourced from the melted snow. Then, the gas supply was cut off. The only source of heat that remained was the generator with a small amount of gasoline. We abandoned using the generator for treatment, but rather used it for cooking and feeding our patients and staff.
To hide from the missiles, we decided to house our patients in the corridors and vault of the Co-60 machine.

“One night I heard a noise from the shattered glass and found a piece of shrapnel (Fig 2). I realized it was becoming very dangerous for our patients to stay in the hospital as the fighting was approaching and becoming more intense. I made a decision to ask the Ukrainian military to start evacuating our patients. It was a well-timed decision, as only 2 hours after the evacuation bus departed, a missile hit our department. (Fig 3)”

“As the shelling intensified to approximately every minute, we decided to leave Mariupol. We did not have any transportation and had to leave the city on foot. While walking out of the city, we were under fire and one of my fellow oncologists was wounded in the leg, but luckily we all survived and after walking 15-18 km along the beach of the Sea of Azov, arrived to a relatively safer area.”

Andrii takes a long contemplative pause and continues: “While staying in the bunker and hearing the whistling of the shells falling next to me, I felt the loss of faith in the big international peace organizations and the purpose they serve. This should not be happening in the 21st century in the heart of Europe. This should not be happening anywhere.”

“Currently, in the occupied Mariupol, we cannot control the radiation equipment or sources. There are no radiation oncologists, physicists, or radiation safety officers there. It really hurts to say that I cannot guarantee the radiation safety, I couldn’t guarantee it then when I was there, but at least it was under my supervision. I do not know what is happening there now nor the fate of the Co-60 source…”

Dr. Hanych was lucky to escape Mariupol alive and currently works as radiation oncologist at Khmelnytskyi antitumor center in the west of Ukraine. According to the Mariupol mayor, an estimated 22,000 of Mariupol residents died in the two months of war, although Guardian reported a staggering 50,000 dead in Mariupol alone (7).

**National Specialized Children’s Hospital OKHMATDYT, Kyiv**

Dr. Yuliia Severyn: “I received the notification about the start of invasion through my work chat channels (Video 3). The radiation therapy department at the National Specialized Children’s Hospital OKHMATDYT was treating 17 patients, 13 of them pediatric patients using the recently upgraded linear accelerator Elekta Synergy. Due to the collapse in transportation system, many of the staff could not get to work, and some of the staff decided to live in the department to enable treatments to continue. The Radiation therapy department located on the 1st floor was used as a bomb shelter: we were housing not only our staff and patients, but also the patients from hematology and neurosurgery departments”.

“Since the full invasion began, we never halted operations and started providing radiotherapy not only for children, but also for adults. On March 2nd, with the help of
“Tabletochki”, a non-profit foundation in Ukraine (8), a few pediatric cancer patients were evacuated to safer areas in the west of Ukraine or abroad, but the majority of parents had not realized the gravity of the situation, and the department still treated approximately 10 pediatric patients a day. On March 9th, only 5 patients remained on treatment in the department, but due to radiotherapy departments closures in the surrounding areas of Kyiv, more adult patients were referred to us. On March 25th, we treated only 6 adult patients, some of whom lived in the department due to the constant air raids in Kyiv and the long curfew hours. Patients felt very grateful, and despite the risk of falling missiles, found, and brought flowers for the staff.”

“The chair of the department, Lyudmyla Vintsevych, two radiation therapists and one medical physicist made the decision to live in the hospital 24/7 to provide diagnostic services for the wounded. The Toshiba CT scanner, usually used for CT simulations, began to be utilized for diagnostic purposes (Fig 4). As the missiles hit and damaged the hospital multiple times, it was important to minimize patient transportation outside between the separate hospital buildings, to keep them safe.

“We started diagnosing the wounded using our CT scanner on April 26th. Our first diagnostic patients were a family with 2 children: a 6 yo boy and a 12 yo girl who had been shot at. The boy was already dead upon arrival, and the girl’s leg was wounded. Parents were in a very difficult physiological state. Almost every day we had a similar case scanning around 5 trauma patients a day, many of whom were children. Bohdana Bachynska, OKHMATDYT’s RTT recounted a 5 yo boy with the large wound on his lower back (Fig 5). She asked him if he was in pain, and he responded: “I am holding on despite the pain”. I think this 5 yo boy is a great metaphor for Ukraine. Ukraine is bleeding but holding on. Another of our radiation therapists, Yana Kuts, served as an emergency technician in the Ukrainian army and frequently accompanied the wounded to OKHMATDYT (Fig 6). They are our department’s heroes.”

“Around mid-April, pediatric patients started to arrive for radiotherapy treatment. As of June 9, we are treating 10 patients, 6 of whom are children. Since the invasion, under the constant threat of missiles and air raids, we treated 26 patients, among them 11 were pediatric patients.” Dr. Severyn takes a long pause, “I will never forget the long row of shoes at the entrance to the department…”

How can we help?

We previously spoke to Dr. Beznosenko, Chief Medical Officer of the National Cancer Institute in Kyiv and the President of the Ukrainian Society of Medical Oncology (9). “There is an acute need for chemotherapy medications and disposable medical devices. The supply chains became disrupted by the war, and the hospital is running out of medication”, said Dr. Beznosenko. Many medical warehouses were destroyed or are unavailable due to logistical issues, airports are not operational, many bridges and highways are damaged. For the centers in the west of Ukraine, with the patient volume doubling, humanitarian help with medication, supplies and staffing are needed to meet the demands. Ruslan Zelinskyi, a President of the Ukrainian Association of Medical
Physicists, Oleksandr Sakharenko, counsel of Aretera Public Affairs, Viktor Iakovenko, medical physicist at UT Southwestern and Nataliya Kovalchuk, medical physicist at Stanford, organized to collect and fundraise for the currently needed disposable immobilization devices for radiotherapy. Vendors (Orfit and CIVCO) are very receptive to helping Ukraine. Union for International Cancer Control (UICC) created Solidarity Fund for Ukraine to bridge the gap and help the organizations caring for cancer patients in Ukraine and surrounding region (10).

Petition your hospital to help Ukraine. Stanford Hospital donated $165,000-worth of medical supplies to Ukraine via Nova Ukraine foundation (11), and Ukrainian Student Association at Stanford together with Nova Ukraine shipped 80 tons ($4 million worth) of medical supplies to Ukraine. Mayo Clinic organized a matched donation fundraising. John Hopkins Medicine and the University of Maryland Medical System donated $4 million worth of medical supplies: personal protective equipment, medical air compressors, syringes, respirator kits — even hospital beds. Zaporizzha city administration is petitioning for a field hospital to take care of the wounded civilians, and we are currently helping with connecting them to donors.

Ukraine, a country of 44 million population, has only 3 PET/CT scanners, all in Kyiv, only 2 of them functioning after the full-scale Russian invasion in February, so the patients from all over Ukraine have to risk their life traveling to Kyiv for a diagnostic scan or follow-up PET/CT scan. According to the European Association of Nuclear Medicine, there should be at least 1 PET/CT scanner per 1.5-2 million people, which would translate into 22 scanners for Ukraine. Together with Nelya Melnitchouk, Oleh Duda, Andriy Beznosenko, we are petitioning PET/CT scanner and cyclotron vendors to donate at least one PET/CT and cyclotron to Lviv Oncology Regional Therapeutic and Diagnostic Center to overcome disparities for Ukrainian cancer patients during the war. Furthermore, Ukraine has cyclotrons with only 18FDG production. Highly specialized centers such as OKHMATDYT and the National Cancer Institute in Kyiv need a cyclotron that produces different tracers.

Asya Agulnik, Director of St. Jude’s Global Critical Care Program has been an amazing driving force at coordinating evacuation and triaging of pediatric patients from Ukraine in collaboration with Tabletochki (Ukrainian non-profit organization helping with evacuation of >850 pediatric cancer patients), and organizations in Poland, Moldova, Italy, Spain, Romania, and Germany. If you visit SAFER Ukraine website (12), you can see the map of the countries and institutions that volunteered to accept hematology/oncology patients and their families from Ukraine. You can petition your cancer center to help bringing Ukrainian pediatric patients for treatment or you can donate to help fundraise to support evacuation of pediatric cancer patients (8).

Andriy Hrynkiv, a surgical oncologist at the Lviv Regional Cancer Center in his speech at the European Cancer Organization – American Society of Clinical Oncology (ECO-ASCO) meeting called for the development of a cancer support network for Ukrainian refugees. ECO and ASCO are urging cancer groups that are able to contribute services,
resources, or contacts to join the network, which can be accessed here (13). We are organizing the sessions on Ukraine at various annual professional meetings (American Society for Radiation Oncology (ASTRO), American Association of Physicists in Medicine (AAPM), Canadian Organization of Medical Physicists (COMP), Medical Physics for World Benefits (MPWB), World Congress on Medical Physics and Biomedical Engineering (IUPESM WC2022)) to inform on the situation in Ukraine with constructive suggestions on how to help Ukraine.

Upon Dr. Beznosenko request, Nelya Melnitchouk, a surgeon at Brigham and Women’s Hospital, and Nataliya Kovalchuk are organizing a training program in US/Canada for the Ukrainian female physicians of various specialties (radiation oncologists, medical oncologists, surgeons, anesthesiologists, pathologists). In parallel, Ruslan Zelinskyi has compiled a list of CVs from Ukrainian female medical physicists, some of them currently displaced. Viktor Iakovenko with Nataliya Kovalchuk are working on finding positions for female Ukrainian medical physicists. Please contact the authors if your institution is willing to provide funding for a visiting scholarship/fellowship for the Ukrainian female doctors or medical physicists. Nelya Melnitchouk through her 501© 3 non-profit organization Global Medical Knowledge Alliance (GMKA) (14) created a fundraiser to help collect funds to cover the travel and initial expenses for Ukrainian female physicians and physicists (15).

Roman Kowalchuk, a radiation oncology resident at Mayo Clinic, is collaborating with the Ukrainian Medical Association of North America (UMANA) (16), a nonprofit organization composed of 19 branches throughout the U.S. and Canada, to help organize telemedicine support for Ukrainian patients. UMANA is working on the telemedicine efforts partnering with Viveo, a telemedicine platform from Estonia, and Doctors4UA, a platform developed by BeKey. A team of Stanford medical and computer science students led by Solomiia Savchuk created a TeleHelp Ukraine initiative to provide remote medical advice and mental health support for Ukrainians with the help of American doctors-volunteers and the team of interpreters. We are grateful to MIM Software Inc. for providing a free software license to host a MIM cloud DICOM repository for medical images for Ukrainian patients that further inform the video consultations. These telemedicine efforts urgently need physicians of every specialty (17-19).

We call on radiation oncology vendors represented in Ukraine such as Varian, Elekta, and Accuray to enhance their support, donate equipment and facilitate the radiation oncology equipment maintenance and service. Ukrainians are grateful to Varian/Siemens Healthineer for creating a €1 million matched fundraiser to help Ukraine with humanitarian needs. Siemens also donated 3 X-ray systems and 4 C-arms to various locations in Ukraine. We are also grateful to Limbus Al Inc. for providing free licenses for automatic contouring software to Ukrainian cancer centers which will facilitate streamlining the treatment planning workflow.

Even if the war were to stop today, the long-lasting effect of the decimated healthcare system in Ukraine will last for years to come. It’s imperative that the effective cancer
recovery plan in Ukraine should have radiotherapy at its heart with precise coordination between governing bodies, professional organization, multidisciplinary professionals, volunteers, and industry (20). However, all these efforts start with individuals, and the individual power and the will of Ukrainians to fight for their people, including their cancer patients, is truly inspiring. Let’s help these Ukrainian doctors-heroes to win over two evils: the cancer and the war.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Figures

Figure 1. Map of the cancer centers providing external beam radiotherapy in Ukraine as of June 2022. Orange radiation symbol denotes Co-60 machines, and blue symbol denotes linear accelerators. Orange arrows show the radiotherapy centers under Russian occupation since 2014, green arrows show the radiotherapy centers under Russian occupation after full-scale invasion in 2022, blue arrows show the centers working under constant shelling as of June 2022, and red arrows show the centers that suspended operation as of June 2022. Source: https://dirac.iaea.org/ supplemented by the data from Ruslan Zelinskyi.
Figure 2. Dr. Andrii Hanych, a chair of Radiation Oncology department at Mariupol Oncological Dispensary, during the interview is showing a piece of shrapnel that hit the hospital while he and his patients were sheltering inside. He made a decision to contact the Ukrainian military to evacuate the patients immediately. A few hours after the evacuation bus departed, the missile hit the radiation oncology department. (Supplement Video 1)
Figure 3. Mariupol oncological dispensary hit by the missile two hours after the patients evacuated. The fate of the Co-60 source is unknown (Supplement Video 2)
Figure 4. OKHMATDYT’s Simulation CT is used for diagnostic purposes. CT scan of the wounded, who unfortunately, died of his wounds.
Figure 5. OKHMATDYT’s staff is taking care of 5-year-old boy wounded in the back (Supplement Video 4).
Figure 6. OKHMATDYT’s RTTs heroes: Bohdana Bachynska (left) and Yana Kuts (right). Bohdana stayed in OKHMATDYT 24/7 to scan wounded patients and Yana serves in Ukrainian army as an emergency medical technician.

Supplement
Supplement Video 1. Interview with Dr. Andriy Hanych, the chair of the Radiation Oncology Department at Mariupol Oncological Dispensary.

Supplement Video 2. Mariupol oncological dispensary hit by the missile two hours after the patients evacuated

Supplement Video 3. Interview with Bohdana Bachynska, a radiation therapist at the National Specialized Children's Hospital OKHMATDYT in Kyiv.