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Special Report

ACCIDENTAL NUCLEAR WAR — A POST–COLD WAR ASSESSMENT

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ABSTRACT

Background In the 1980s, many medical organizations identified the prevention of nuclear war as one of the medical profession's most important goals. An assessment of the current danger is warranted given the radically changed context of the post–Cold War era.

Methods We reviewed the recent literature on the status of nuclear arsenals and the risk of nuclear war. We then estimated the likely medical effects of a scenario identified by leading experts as posing a serious danger: an accidental launch of nuclear weapons. We assessed possible measures to reduce the risk of such an event.

Results U.S. and Russian nuclear-weapons systems remain on high alert. This fact, combined with the aging of Russian technical systems, has recently increased the risk of an accidental nuclear attack. As a conservative estimate, an accidental intermediate-sized launch of weapons from a single Russian submarine would result in the deaths of 6,838,000 persons from firestorms in eight U.S. cities. Millions of other people would probably be exposed to potentially lethal radiation from fallout. An agreement to remove all nuclear missiles from high-level alert status and eliminate the capability of a rapid launch would put an end to this threat.

Conclusions The risk of an accidental nuclear attack has increased in recent years, threatening a public health disaster of unprecedented scale. Physicians and medical organizations should work actively to help build support for the policy changes that would prevent such a disaster. (N Engl J Med 1998; 338:1326-31.)

DURING the Cold War, physicians and others described the potential medical consequences of thermonuclear war and concluded that health care personnel and facilities would be unable to provide effective care to the vast number of victims of a nuclear attack.[1-3] In 1987, a report by the World Health Organization concluded, "The only approach to the treatment of health effects of nuclear warfare is primary prevention, that is, the prevention of nuclear war."[4] Many physicians and medical organizations have argued that the prevention of nuclear war should be one of the medical profession's most important goals.[5-9]

CONTINUED DANGER OF A NUCLEAR ATTACK

Although many people believe that the threat of a nuclear attack largely disappeared with the end of the Cold War, there is considerable evidence to the contrary.[10] The United States and Russia no longer confront the daily danger of a deliberate, massive nuclear attack, but both nations continue to operate nuclear forces as though this danger still existed. Each side routinely maintains thousands of nuclear warheads on high alert. Furthermore, to compensate for its weakened conventional armed forces, Russia has abandoned its "no first use" policy.[11]

Even though both countries declared in 1994 that they would not aim strategic missiles at each other, not even one second has been added to the time required to launch a nuclear attack: providing actual targeting (or retargeting) instructions is simply a component of normal launch procedures.[12-14] The default targets of U.S. land-based missiles are now the oceans, but Russian missiles launched without specific targeting commands automatically revert to previously programmed military targets.[13]

There have been numerous "broken arrows" (major nuclear-weapons accidents) in the past, including at least five instances of U.S. missiles that are capable of carrying nuclear devices flying over or crashing in or near the territories of other nations.[15,16] From 1975 to 1990, 66,000 military personnel involved in the operational aspects of U.S. nuclear forces were removed from their positions. Of these 66,000, 41 per-

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cent were removed because of alcohol or other drug abuse and 20 percent because of psychiatric problems.[17,18] General George Lee Butler, who as commander of the U.S. Strategic Command from 1991 to 1994 was responsible for all U.S. strategic nuclear forces, recently reported that he had "investigated a dismaying array of accidents and incidents involving strategic weapons and forces."[19]

Any nuclear arsenal is susceptible to accidental, inadvertent, or unauthorized use.[20,21] This is true both in countries declared to possess nuclear weapons (the United States, Russia, France, the United Kingdom, and China) and in other countries widely believed to possess nuclear weapons (Israel, India, and Pakistan). The combination of the massive size of the Russian nuclear arsenal (almost 6000 strategic warheads) and growing problems in Russian control systems makes Russia the focus of greatest current concern.

Since the end of the Cold War, Russia's nuclear command system has steadily deteriorated. Aging nuclear communications and computer networks are malfunctioning more frequently, and deficient early-warning satellites and ground radar are more prone to reporting false alarms.[10,22-24] The saga of the Mir space station bears witness to the problems of aging Russian technical systems. In addition, budget cuts have reduced the training of nuclear commanders and thus their proficiency in operating nuclear weapons safely. Elite nuclear units suffer pay arrears and housing and food shortages, which contribute to low morale and disaffection. New offices have recently been established at Strategic Rocket Forces bases to address the problem of suicide[25] (and unpublished data).

Safeguards against a nuclear attack will be further degraded if the Russian government implements its current plan to distribute both the unlock codes and conditional launch authority down the chain of command. Indeed, a recent report by the Central Intelligence Agency, which was leaked to the press, warned that some Russian submarine crews may already be capable of authorizing a launch.[26] As then Russian Defense Minister Igor Rodionov warned last year, "No one today can guarantee the reliability of our control systems. . . . Russia might soon reach the threshold beyond which its rockets and nuclear systems cannot be controlled."[24]

A particular danger stems from the reliance by both Russia and the United States on the strategy of "launch on warning" — the launching of strategic missiles after a missile attack by the enemy has been detected but before the missiles actually arrive. Each country's procedures allow a total response time of only 15 minutes: a few minutes for detecting an enemy attack, another several minutes for top-level decision making, and a couple of minutes to disseminate the authorization to launch a response.[27,28]

Possible scenarios of an accidental or otherwise unauthorized nuclear attack range from the launch of a single missile due to a technical malfunction to the launch of a massive salvo due to a false warning. A strictly mechanical or electrical event as the cause of an accidental launch, such as a stray spark during missile maintenance, ranks low on the scale of plausibility.[29] Analysts also worry about whether computer defects in the year 2000 may compromise the control of strategic missiles in Russia, but the extent of this danger is not known.

Several authorities consider a launch based on a false warning to be the most plausible scenario of an accidental attack.[20,29] This danger is not merely theoretical. Serious false alarms occurred in the U.S. system in 1979 and 1980, when human error and computer-chip failures resulted in indications of a massive Soviet missile strike.[10,30] On January 25, 1995, a warning related to a U.S. scientific rocket launched from Norway led to the activation, for the first time in the nuclear era, of the "nuclear suitcases" carried by the top Russian leaders and initiated an emergency nuclear-decision-making conference involving the leaders and their top nuclear advisors. It took about eight minutes to conclude that the launch was not part of a surprise nuclear strike by Western submarines — less than four minutes before the deadline for ordering a nuclear response under standard Russian launch-on-warning protocols.[10,24,27]

A missile launch activated by false warning is thus possible in both U.S. and Russian arsenals. For the reasons noted above, an accidental Russian launch is currently considered the greater risk. Several specific scenarios have been considered by the Ballistic Missile Defense Organization of the Department of Defense.[31] We have chosen to analyze a scenario that falls in the middle range of the danger posed by an accidental attack: the launch against the United States of the weapons on board a single Russian Delta-IV ballistic-missile submarine, for two reasons. First, the safeguards against the unauthorized launch of Russian submarine-based missiles are weaker than those against either silo-based or mobile land-based rockets, because the Russian general staff cannot continuously monitor the status of the crew and missiles or use electronic links to override unauthorized launches by the crews. Second, the Delta-IV is and will remain the mainstay of the Russian strategic submarine fleet.[27,32,33]

Delta-IV submarines carry 16 missiles. Each missile is armed with four 100-kt warheads and has a range of 8300 km, which is sufficient to reach almost any part of the continental United States from typical launch stations in the Barents Sea.[34,35] These missiles are believed to be aimed at "soft" targets, usually in or near American cities, whereas the more accurate silo-based missiles would attack U.S. mili-

tary installations.[36] Although a number of targeting strategies are possible for any particular Delta-IV, it is plausible that two of its missiles are assigned to attack war-supporting targets in each of eight U.S. urban areas. If 4 of the 16 missiles failed to reach their destinations because of malfunctions before or after the launch, then 12 missiles carrying a total of 48 warheads would reach their targets.

POTENTIAL CONSEQUENCES OF A NUCLEAR ACCIDENT

We assume that eight U.S. urban areas are hit: four with four warheads and four with eight warheads. We also assume that the targets have been selected according to standard military priorities: industrial, financial, and transportation sites and other components of the infrastructure that are essential for supporting or recovering from war. Since low-altitude bursts are required to ensure the destruction of structures such as docks, concrete runways, steel-reinforced buildings, and underground facilities, most if not all detonations will cause substantial early fallout.

Physical Effects

Under our model, the numbers of immediate deaths are determined primarily by the area of the "superfires" that would result from a thermonuclear explosion over a city. Fires would ignite across the exposed area to roughly 10 or more calories of radiant heat per square centimeter, coalescing into a giant firestorm with hurricane-force winds and average air temperatures above the boiling point of water. Within this area, the combined effects of superheated wind, toxic smoke, and combustion gases would result in a death rate approaching 100 percent.[37]

For each 100-kt warhead, the radius of the circle of nearly 100 percent short-term lethality would be 4.3 km (2.7 miles), the range within which 10 cal per square centimeter is delivered to the earth's surface from the hot fireball under weather conditions in which the visibility is 8 km (5 miles), which is low for almost all weather conditions. We used Census CD to calculate the residential population within these areas according to 1990 U.S. Census data, adjusting for areas where circles from different warheads overlapped.[38] In many urban areas, the daytime population, and therefore the casualties, would be much higher.

Fallout

The cloud of radioactive dust produced by low-altitude bursts would be deposited as fallout downwind of the target area. The exact areas of fallout would not be predictable, because they would depend on wind direction and speed, but there would be large zones of potentially lethal radiation exposure. With average wind speeds of 24 to 48 km per hour (15 to 30 miles per hour), a 100-kt low-altitude detonation would result in a radiation zone 30 to 60 km (20 to 40 miles) long and 3 to 5 km (2 to 3 miles) wide in which exposed and unprotected persons would receive a lethal total dose of 600 rad within six hours.[39] With radioactive contamination of food and water supplies, the breakdown of refrigeration and sanitation systems, radiation-induced immune suppression, and crowding in relief facilities, epidemics of infectious diseases would be likely.[40]

Deaths

Table 1 shows the estimates of early deaths for each cluster of targets in or near the eight major urban areas, with a total of 6,838,000 initial deaths. Given the many indeterminate variables (e.g., the altitude of each warhead's detonation, the direction of the wind, the population density in the fallout zone, the effectiveness of evacuation procedures, and the availability of shelter and relief supplies), a reliable estimate of the total number of subsequent deaths from fallout and other sequelae of the attack is not possible. With 48 explosions probably resulting in thousands of square miles of lethal fallout around urban areas where there are thousands of persons per square mile, it is plausible that these secondary deaths would outnumber the immediate deaths caused by the firestorms.

Medical Care in the Aftermath

Earlier assessments have documented in detail the problems of caring for the injured survivors of a nuclear attack: the need for care would completely overwhelm the available health care resources.[1-5,41] Most of the major medical centers in each urban area lie within the zone of total destruction. The number of patients with severe burns and other critical injuries would far exceed the available resources of all critical care facilities nationwide, including the country's 1708 beds in burn-care units (most of which are already occupied).[42] The danger of intense radiation exposure would make it very difficult for emergency personnel even to enter the affected areas. The nearly complete destruction of local and regional transportation, communications, and energy networks would make it almost impossible to transport the severely injured to medical facilities outside the affected area. After the 1995 earthquake in Kobe, Japan, which resulted in a much lower number of casualties (6500 people died and 34,900 were injured) and which had few of the complicating factors that would accompany a nuclear attack, there were long delays before outside medical assistance arrived.[43]

FROM DANGER TO PREVENTION

Public health professionals now recognize that many, if not most, injuries and deaths from violence

TABLE 1. PREDICTED IMMEDIATE DEATHS FROM FIRESTORMS AFTER NUCLEAR DETONATIONS IN EIGHT U.S. CITIES

CITY*	NO. OF WARHEADS	NO. OF DEATHS
Atlanta	8	428,000
Boston	4	609,000
Chicago	4	425,000
New York	8	3,193,000
Pittsburgh	4	375,000
San Francisco Bay area	8	739,000
Seattle	4	341,000
Washington, D.C.	8	728,000
Total	48	6,838,000

*The specific targets are as follows: Atlanta — Peachtree Airport, Dobbins Air Force Base, Fort Gillem, Fort McPherson, Fulton County Airport, Georgia Institute of Technology, Hartsfield Airport, and the state capitol; Boston — Logan Airport, Commonwealth Pier, Massachusetts Institute of Technology, and Harvard University; Chicago — Argonne National Laboratory, City Hall, Midway Airport, and O'Hare Airport; New York — Columbia University, the George Washington Bridge, Kennedy Airport, LaGuardia Airport, the Merchant Marine Academy, Newark Airport, the Queensboro Bridge, and Wall Street; Pittsburgh — Carnegie Mellon University, Fort Duquesne Bridge, Fort Pitt Bridge, Pittsburgh Airport, and the U.S. Steel plant; San Francisco Bay area — Alameda Naval Air Station, the Bay Bridge, Golden Gate Bridge, Moffet Field, Oakland Airport, San Francisco Airport, San Jose Airport, and Stanford University; Seattle — Boeing Field, Seattle Center, Seattle–Tacoma Airport, and the University of Washington; and Washington, D.C. — the White House, the Capitol Building, the Pentagon, Ronald Reagan National Airport, College Park Airport, Andrews Air Force Base, the Defense Mapping Agency, and Central Intelligence Agency headquarters.

and accidents result from a predictable series of events that are, at least in principle, preventable.[44,45] The direct toll that would result from an accidental nuclear attack of the type described above would dwarf all prior accidents in history. Furthermore, such an attack, even if accidental, might prompt a retaliatory response resulting in an all-out nuclear exchange. The World Health Organization has estimated that this would result in billions of direct and indirect casualties worldwide.[4]

Limitations of Ballistic-Missile Defense

There are two broad categories of efforts to avert the massive devastation that would follow the accidental launch of nuclear weapons: interception of the launched missile in a way that prevents detonation over a populated area and prevention of the launch itself. Intercepting a launched ballistic missile might appear to be an attractive option, since it could be implemented unilaterally by a country. To this end, construction of a U.S. ballistic-missile defense system has been suggested. Unfortunately, the technology for ballistic-missile defense is unproved, and even its most optimistic advocates predict that it cannot be fully protective. Furthermore, the estimated costs would range from $4 billion to $13 billion for a single-site system to $31 billion to $60 billion for a multiple-site system.[46,47] In either case, the system would not be operational for many years.[48]

A Bilateral Agreement to Eliminate High-Level Alert Status

Since ballistic-missile defense offers no solution at all in the short term and at best an expensive and incomplete solution in the long term, what can the United States as well as other nations do to reduce the risk of an accidental nuclear attack substantially and quickly? The United States should make it the most urgent national public health priority to seek a permanent, verified agreement with Russia to take all nuclear missiles off high alert and remove the capability of a rapid launch.[49] This approach is much less expensive and more reliable than ballistic-missile defense and can be implemented in short order. In various forms, such an agreement has been urged by the National Academy of Sciences,[50] the Canberra Commission,[51] General Butler and his military colleagues throughout the world,[52] and other experts, such as Sam Nunn, former chairman of the U.S. Senate Armed Services Committee, and Stansfield Turner, former director of the Central Intelligence Agency.[10,20,53] The Joint Chiefs of Staff and an interagency working group are completing a detailed study of de-alerting options that will be presented to Defense Secretary William Cohen.[10]

Major improvements in nuclear stability can be achieved rapidly. In the wake of the 1991 attempted coup in Moscow, Presidents George Bush and Mikhail Gorbachev moved quickly to enhance nuclear safety and stability by taking thousands of strategic weapons off high alert almost overnight.[27] Today, there are specific steps that the United States can take almost immediately, since they require only the authority of a presidential directive. These steps include putting in storage the warheads of the MX missiles, which will be retired under Strategic Arms Reduction Treaty (START) II in any case, and the warheads of the four Trident submarines that will be retired under START III; placing the remaining U.S. ballistic-missile submarines on low alert so that it would take at least 24 hours to prepare them to launch their missiles; disabling all Minuteman III missiles by pinning their safety switches open (as was done with the Minuteman II missiles under President Bush's 1991 directive); and allowing Russia to verify these actions with the on-site inspections allowed under START I. Similar measures should be taken by the Russians.[27,49] These steps — all readily reversible if warranted by future developments or if a permanent bilateral agreement is not reached — would eliminate today's dangerous launch-on-warning systems, making the U.S. and Russian popula-

tions immediately safer. Both nations should then energetically promote a universal norm against maintaining nuclear weapons on high alert.

The Role of Physicians

In awarding the 1985 Nobel Peace Prize to International Physicians for the Prevention of Nuclear War, the Nobel Committee underscored the "considerable service to mankind" that physicians have performed by "spreading authoritative information and by creating an awareness of the catastrophic consequences of atomic warfare. This in turn contributes to an increase in the pressure of public opposition to the proliferation of nuclear weapons and to a redefining of priorities . . ."[54] No group is as well situated as physicians to help policy makers and the public fully appreciate the magnitude of the disaster that can ensue if changes in the alert status of all nuclear weapons are not instituted.[5,6,8,9,55-57]

The only way to make certain that an accidental (or any other) nuclear attack never occurs is through the elimination of all nuclear weapons and the airtight international control of all fissile materials that can be used in nuclear weapons. In 1995, the World Court stated that the abolition of nuclear weapons is a binding legal obligation of the United States, Russia, and all signatories to the Nuclear Nonproliferation Treaty, under Article 6.[58] Preferring the term "prohibition" to "abolition," the Committee on International Security and Arms Control of the U.S. National Academy of Sciences concluded in its 1997 report, "The potential benefits of comprehensive nuclear disarmament are so attractive relative to the attendant risks — and the opportunities presented by the end of the Cold War . . . are so compelling — that . . . increased attention is now warranted to studying and fostering the conditions that would have to be met to make prohibition desirable and feasible."[59]

Leading U.S. medical organizations, including the American College of Physicians and the American Public Health Association, have already joined Physicians for Social Responsibility, International Physicians for the Prevention of Nuclear War, and over 1000 other nongovernmental organizations in 75 nations to support Abolition 2000, which calls for a signed agreement by the year 2000 committing all countries to the permanent elimination of nuclear weapons within a specified time frame.[60-63] The American Medical Association has recently endorsed the abolition of nuclear weapons,[64] as have the Canberra Commission,[51] military leaders throughout the world,[52] major religious organizations,[61,65] and over 100 current and recent heads of state and other senior political leaders.[66,67] Some supporters of the abolition of nuclear weapons have specifically called for immediate steps to eliminate the high-level alert status of such weapons, as urgent interim measures. All parties should cooperate to ensure that these measures are implemented rapidly.

CONCLUSIONS

The time, place, and circumstances of a specific accident are no more predictable for nuclear weapons than for other accidents. Nonetheless, as long as there is a finite, nonzero, annual probability that an accidental launch will occur, then given sufficient time, the probability of such a launch approaches certainty. Until the abolition of nuclear weapons reduces the annual probability to zero, our immediate goal must be to reduce the probability of a nuclear accident to as low a level as possible. Given the massive casualties that would result from such an accident, achieving this must be among the most urgent of all global public health priorities.

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