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INDICATORS OF THE TEMPORARY CAVITY DURING SHOTS FROM NON-LETHAL FIREARMS: AN EXPERIMENTAL STUDY USING THE "FORT 9R" AND "FORT 17R" PISTOLS

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The effect of non-lethal firearms on the human body with or without clothing is one of the least researched issues in forensic ballistics, which requires a controlled experimental study.

The aim of the study – to determine the characteristics of the indicators of the temporal cavity on naked or clothed non-biological simulators of the human body when fired from different distances using "Fort 9R" and "Fort 17R" pistols.

Materials and methods. The study was carried out on 120 gelatin blocks, which were left bare or covered with one of the types of fabrics: cotton fabric, denim fabric, leatherette, after which shooting was carried out using "Fort 9R" (1st group – 60 blocks) or "Fort 17R" (2nd group – 60 blocks). Shots were fired from contact range, 25 and 50 cm. Subsequently, sections of the blocks were made perpendicular to the wound channel. Each section was examined according to generally accepted methods in order to assess the dimensions of the temporal cavity.

Results. The analysis of the obtained data revealed numerous reliable differences in the investigated parameters of the temporal cavity both between the "Fort 9R" and "Fort 17R" pistols and the investigated samples of clothing that covered the blocks. When comparing pistols, in most cases significantly higher values ($p<0.05$-0.01) of temporary cavity indicators were established for the "Fort 9R" pistol. When comparing the protective properties of different types of clothing, significantly lower values ($p<0.05$-0.01) of the indicators of the temporary cavity when fired with "Fort 9R" were obtained when studying blocks covered with cotton fabric; when firing from "Fort 17R" clothing, significantly lower values ($p<0.05$–0.01) of the indicators of the temporary cavity were obtained when analyzing the data of the blocks covered with leather substitute.

Key words: temporary cavity, firearm, gunshot injury, gunshot wounds, non-biological simulator of the human body.

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ПОКАЗНИКИ ТИМЧАСОВОЇ ПОРОЖНИНИ ПІД ЧАС ПОСТРІЛІВ ІЗ НЕЛЕТАЛЬНОЇ ВОГНЕПАЛЬНОЇ ЗБРОЇ: ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ІЗ ЗАСТОСУВАННЯМ ПІСТОЛЕТІВ «ФОРТ 9Р» ТА «ФОРТ 17Р»

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Стаття присвячена вивченню особливості параметрів тимчасової порожнини у разі пострілів з пістолетів нелетальної дії вітчизняного виробництва – «Форт 9Р» та «Форт 17Р» у голі або вкриті різними видами одягу небіологічні імітатори тіла людини (желатинові блоки). У результаті проведених експериментальних відстрілів з послідуючим дослідженням утворених ушкоджень встановлено, що пістолет «Форт 9Р» спричинює утворення тяжчих ушкоджень, ніж «Форт 17Р», а різні види одягу мають специфічні захисні властивості, що дозволяють зменшити тяжкість ушкоджень за рахунок зменшення розмірів тимчасової порожнини, а саме: бавовняна тканина краще захищає у разі пострілів з «Форт 9Р», тоді як шкірозамінник краще захищає у разі пострілів з «Форт 17Р».

Ключові слова: тимчасова порожнина, вогнепальна зброя, вогнепальна травма, вогнепальні ушкодження, небіологічний імітатор тіла людини.

Introduction. Firearms became widely distributed among different strata of the population, which, accordingly, led to the spread of various ways of their use. In addition to the primary, protective or hunting function, it is used by criminals for the purpose of committing various criminal acts that can result in both injury and death; sometimes firearms are used for suicide. Sometimes careless handling of firearms can lead to injury or death. Thus, in 2006, 11 cases of death from firearms were recorded in the city of Ibadan (Nigeria), which was 1.6% of the total number of forensic examinations. 10 cases out of 11 were murders. 36% of criminals used illegally acquired weapons [1]. An analysis of deaths in Naples from 1981 to 2011 found 200 deaths caused by firearms, of which 188 were homicides (most of the dead were between the ages of 20 and 39). Suicide was recorded in only 11 cases (most of the people over 50 years old). A total of 772 gunshot wounds were recorded on the bodies of 200 dead people. Most of them (658) were committed with the use of pistols [3].

The topic of studying firearms in Ukraine became relevant after 2014. For the first time, the forensic medical system encountered a large number of injured and dead persons from the use of lethal and non-lethal firearms precisely

during the events on the Independence Square [6]. Taking into account the further Russian invasion of Ukraine, the creation of new and new types of weapons, in particular, non-lethal weapons, the law enforcement system needs more knowledge about ballistics from forensic medical experts and criminologists.

One of the important aspects of ballistics that should be taken into account is wound ballistics, namely the process of formation of temporary cavities in the human body during the passage of ammunition through it, how its parameters are affected by various circumstances, types of clothing, etc. [5]. In this regard, there is a need to conduct controlled experimental ballistic tests, which will primarily take into account the samples of non-lethal firearms common in Ukraine.

The aim of the study – to determine and compare the features of the indicators of the temporary cavity formed when shots were fired from "Fort 9R" and "Fort 17R" pistols in the naked body or non-biological imitators of the human body covered with different types of tissue when fired at contact range, 25 and 50 cm.

Materials and methods of research. Using the method of Fackler and Malinowski [2], 120 gelatin blocks were made, which were further divided into two equal groups (60 blocks each) according to the gun from which they were to be fired, namely "Fort 9R" and "Fort 17R", which were equipped with 9 mm cartridges, elastic bullets of traumatic effect. In each group, 4 subgroups were formed according to the covering of the block: 1st group – bare blocks (BB), 2nd group – blocks covered with cotton fabric (CF), 3rd group – blocks covered with denim fabric (DF), 4th group – blocks covered with leatherette (LB). Shots were fired from three different distances: at contact range, 25 and 50 cm. After the shot, the blocks were cut perpendicular to the wound channel with an interval of 1 cm.

Later, the following methods were used to estimate the parameters of the temporary cavity for each section: the total crack length method (TCLM) [2], the Fackler's wound profile method (FWPM) [8] and the polygon-procedure method (PPM) [10]. The results were photographed in accordance with the rules of forensic photography using an Alpha A6000 Sony digital camera.

The work was carried out as part of the research work of the National Pirogov Memorial Medical University, Vinnytsia at the expense of state funding of the Ministry of Health of Ukraine: "Characteristics of damage to human body tissue simulators caused by non-lethal weapons" (state registration number 0121U107924).

Committee on Bioethics of National Pirogov Memorial Medical University, Vinnytsia (protocol № 11 From 03.12.2020) found that the studies do not contradict the basic bioethical standards of the Declaration of Helsinki, the Council of Europe Convention on Human Rights and Biomedicine (1977), the relevant WHO regulations and laws of Ukraine.

The statistical analysis of the obtained results was carried out in the licensed statistical package "Statistica 6.0" using non-parametric estimation methods. The reliability of the difference in values between independent quantitative values was determined using the Mann-Whitney U-test, and between qualitative values – according to the Weber E.

The results of the research and their discussion. When analyzing the values of the *TCLM* indicator obtained as a result of a shot from the "Fort 9R" and "Fort 17R" pistols, the following features were revealed: at a cut depth of 1 cm when contact firing from "Fort 9R" in CF, significantly ($p<0.05–0.01$) lower values of the index were found compared to BB, DF and LB (5.940±1.438, 11.58±1.70, 10.00±1.87 and 9.240±2.25 in accordance); when shooting from a distance of 25 cm, BB showed significantly ($p<0.01$) higher values of the indicator compared to CF, DF and LB (7.620±0.736, 2.420±0.638, 4.200±0.543 and 2.860±0.799, respectively) and significantly ($p<0.05$-0.01) higher values of the indicator for shots in DF compared to CF and LB (4.200±0.543, 2.420±0.638 and 2.860±0.799, respectively); when shooting from a distance of 50 cm, significantly ($p<0.05$) lower indicator values were found in CF compared to DF and LB (1.400±0.292, 2.800±0.812 and 2.340±0.820, respectively).

When firing from "Fort 17R" at contact range, significantly ($p<0.05$) lower values of the indicator were found in DF compared to BB, CF and LB (6.380±0.920, 8.640±1.060, 9.940±1.696 and 8.320±1.551, respectively); when shooting from a distance of 25 cm, BB showed significantly ($p<0.01$) higher values of the indicator compared to CF, DF and LB (7.280±1.701, 4.200±0.656, 2.560±0.541 and 4.460±0.669, respectively) and significantly ($p<0.01$) lower values of the indicator when shooting in DF compared to CF and LB (2.560±0.541, 4.200±0.656 and 4.460±0.669, respectively); when shooting from a distance of 50 cm, significantly ($p<0.01$) higher values of the indicator were found in BB compared to LB (1.760±0.344 and 1.180±0.228, respectively).

When comparing the values of the indicator when shooting from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except for LB when shooting with "Fort 9R" for distances of 25–50 cm and BB when shooting with "Fort 17R" close to 25 cm.

When comparing the values of the indicator when fired from the "Fort 9R" and "Fort 17R" pistols, significantly ($p<0.05$-0.01) higher values were found when fired from the "Fort 9R" in BB at contact range, at DF for all distances and for LB at shots from a distance of 50 cm (11.58±1.70 and 8.640±1.060, 10.00±1.87 and 6.380±0.920, 4.200±0.543 and 2.560±0.541, 2.800±0.812 and 1.400±0.524, 2.340±0.820 and 1.180±0.228, respectively) and when shooting from "Fort 17R" in CF at contact range, from a distance of 25 cm and in LB from a distance of 50 cm (9.940±1.696 and 5.940±1.438, 4.200±0.656 and 2.420±0.638, 4.460 ±0.669 and 2.860±0.799, respectively).

At the depth of the cut of 2 cm, with shots from "Fort 9R" from a distance of 25 cm, significantly ($p<0.01$) higher values of the indicator were found in BB compared to CF, DF and LB (5.640±1.717, 2.340±0.684, 1.060±0.709 and 2.280±0.638, respectively) and significantly ($p<0.05$) lower values of the indicator when shooting in DF compared to CF and LB (1.060±0.709, 2.340±0.684 and 2.280±0.638, respectively); when shooting from a distance of 50 cm, significantly ($p<0.05$) lower values of the indicator were found when shooting at BB compared to CF (0.860±0.611 and 2.220±1.006, respectively).

When shooting from "Fort 17R" at contact range, significantly ($p<0.01$) higher values of the indicator were found when shooting at BB or CF compared to DF and LB (10.80±1.81, 11.22±2.38, 5.620±1.043 and 5.680±1.497, respectively); when shooting from a distance of 25 cm, significantly ($p<0.05$-0.01) lower values of the indicator were found when shooting at DF compared to BB and LB (1.780±1.026, 4.100±0.644 and 3.480±0.792, respectively).

When comparing the values of the indicator when fired from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except for CF and DF when fired from "Fort 9R" from distances of 25–50 cm, DF at shots from the "Fort 17R" from a distance of 25–50 cm and LB at close range – 25 cm.

When comparing the values of the indicator for shots from the "Fort 9R" and "Fort 17R" pistols, it is reliable ($p<0.05$-0.01) its higher values were found when shooting from "Fort 9R" in CF from a distance of 50 cm, DF and LB contact (2.220±1.006 and 0.800±0.235, 10.74±1.81 and 5.620±1.043, 11.22±0.77 and 5.680±1.497, respectively) and reliably ($p<0.05$) its higher values were found when firing from "Fort 17R" in LB from a distance of 25 cm (3.480±0.792 and 2.280±0.638, respectively).

At a cut depth of 3 cm when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range (except for BB when fired from the "Fort 9R"). In all groups, except for CF, significantly ($p<0.05$-0.01) higher parameter values were recorded with shots from the "Fort 9R" pistol (BB 15.60±2.42 and 11.30±1.64, DF 10.04±1.69 and 3.200±0.424, LB 9.500±0.930 and 0.740±0.684).

At a cut depth of 4 cm, when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range. In all groups, except for CF, significantly ($p<0.05$-0.01) higher parameter values were recorded with shots from the "Fort 9R" pistol (BB 9.620±3.549 and 4.200±1.759, DF 4.540±0.684 and 0.320±0.716, LB 5.280±1.548 and 0).

At a cut depth of 5 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB and DF; at the depth of the cut of 6 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB.

When analyzing the values of the *FWPM* indicator obtained as a result of a shot from the "Fort 9R" and "Fort 17R" pistols, the following features were revealed: at a cut depth of 1 cm when fired from a "Fort 9R" pistol at contact range, significantly ($p<0.05$-0.01) lower values of the parameter were found when fired at CF compared to BB and DF (1.760±0.207, 2.580±0.377 and 2.360± 0.114 respectively); when shooting from a distance of 25 cm, significantly ($p<0.01$) higher parameter values were found when shooting BB compared to CF, DF, LB (2.340±0.261, 1.160±0.182, 1.440±0.195 and 1.360±0.336, respectively) and significantly ($p<0.05$) higher values of the parameter when firing in DF compared to CF (1.440±0.195 and 1.160±0.182, respectively); when shooting from a distance of 50 cm, significantly ($p<0.05$) lower values of the parameter were found when shooting in CF compared to DF and LB (0.720±0.045, 1.180±0.303 and 1.060±0.305, respectively).

When fired from a "Fort 17R" pistol at contact range, significantly ($p<0.05$) lower values of the parameter were found when fired at CF compared to LB (1.780±0.239 and 2.020±0.045, respectively); when shooting from a distance of 25 cm, significantly ($p<0.05$) higher values of the parameter were found when shooting at BB compared to CF, DF and LB (2.080±0.148, 1.640±0.167, 1.580±0.277 and 1.520±0.259, respectively).

When comparing the values of the indicator when fired from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except "Fort 9R" for BB at close range – 25 cm, DF and LB – 25–50 cm and besides "Fort 17R" close – 25 cm for BB, CF and DF.

When comparing the values of the indicator when fired from the "Fort 9R" and "Fort 17R" pistols, significantly ($p<0.05$-0.01) higher values were found when fired from the "Fort 9R" at DF at contact range, at a distance of 50 cm, and at a distance of LB 50 cm (2.360±0.114 and 1.940±0.261, 1.180±0.303 and 0.740±0.241, 1.060±0.305 and 0.660±0.207, respectively) and for "Fort 17R" when fired from a distance of 25 cm in CF (1.640±0.167 and 1.16 0±0.182 in accordance).

At a cut depth of 2 cm when fired from a "Fort 9R" pistol at contact range, significantly ($p<0.05$-0.01) higher values of the parameter were detected when fired at BB compared to CF and DF (3.240±0.344, 2.400±0.412 and 2.760± 0.182, respectively); when shooting from a distance of 25 cm, significantly ($p<0.01$) higher parameter values were found when shooting BB compared to CF, DF, LB (2.160±0.114, 1.240±0.152, 0.680±0.444 and 1.180±0.164, respectively) and significantly lower ($p <0.05$) value of the parameter when shooting in DF compared to CF and LB (0.680±0.444, 1.240±0.152 and 1.180±0.164, respectively).

When fired from a "Fort 17R" pistol at contact range, significantly ($p<0.05$-0.01) lower values of the parameter were found when fired at LB compared to BB and DF (1.860±0.251, 2.580±0.130 and 2.460±0.404, respectively); when shooting from a distance of 25 cm, significantly ($p<0.05$) higher values of the parameter were found when shooting at BB compared to DF and LB (1.940±0.251, 1.140±0.684 and 1.500±0.122, respectively).

When comparing the values of the indicator when shooting from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except for "Fort 9R" for CF, DF and LB 25–50 cm and "Fort 17R" for DF 25–50 cm.

When comparing the values of the indicator when fired from the "Fort 9R" and "Fort 17R" pistols, significantly ($p<0.05$-0.01) higher values were found when contact fired from the "Fort 9R" to the BB, 50 cm in DF and close and 25 cm in LB (3.240±0.344 and 2.580±0.130, 0.940±0.410 and 0.460±0.397, 2.860±0.391 and 1.860±0.251, 1.180±0.164 and 1.500±0.122).

At a cut depth of 3 cm when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range (except for BB when fired from the "Fort 9R"). In all groups, except for CF, significantly ($p<0.05$–0.01) higher values of the parameters were recorded with shots from the "Fort 9R" pistol

(BB 3.640±0.365 and 3.180±0.492, DF 3.020±0.179 and 1.980±0.295, LB 3.040±0.321 and 0.600±0.561).

At a cut depth of 4 cm, when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range. In all groups, except for CF, significantly ($p<0.05–0.01$) higher values of the parameters were recorded with shots from the "Fort 9R" pistol (BB 3.340±0.336 and 2.460±0.733, DF 2.120±0.130 and 0.260±0.581, LB 2.260±0.434 and 0). At a cut depth of 5 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB and DF; at the depth of the cut of 6 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB.

When analyzing the values of the *PPM* indicator obtained as a result of a shot from the "Fort 9R" and "Fort 17R" pistols, the following features were revealed: at a cut depth of 1 cm when contact firing from "Fort 9R", significantly lower ($p<0.05$) indicator values were established for CF compared to BB and LB (6.900±1.111, 9.300±1.353 and 8.180±1.073, respectively); with shots from 25 cm, significantly higher ($p<0.01$) indicator values were established for BB compared to CF, DF and LB (6.500±0.505, 3.300±0.453, 3.760±0.434 and 3.680±0.277, respectively); when shooting from 50 cm, significantly higher ($p<0.05$) indicator values were established for BB compared to CF (2.940±0.568 and 2.040±0.451, respectively).

When contact shooting from "Fort 17R", significantly higher ($p<0.05$-0.01) values of the indicator were established for BB or CF compared to DF and LB (7.440±0.635, 7.540±0.780, 5.920±0.729 and 5.540±0.416, respectively); with shots from 25 cm, significantly higher ($p<0.01$) values of the indicator were established for BB compared to CF, DF and LB (5.720±0.432, 4.060±0.835, 3.520±0.638 and 3.560±0.351, respectively); with shots from 50 cm, significantly higher ($p<0.05$) values of the indicator were established for BB compared to CF and LB (2.480±0.249, 2.100±0.158 and 1.900±0.332, respectively).

When comparing the values of the indicator when fired from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except "Fort 9R" for DF 25–50 cm.

When comparing the values of the indicator when fired from pistols "Fort 9R" and "Fort 17R" significantly ($p<0.05–0.01$) higher values were found when contact shooting with "Fort 9R" to BB, DF and LB and DF 50 cm (9.300±1.353 and 7.440±0.635, 7.980±0.701 and 5.920±0.729, 8.180±1.073 and 5.540±0.416, 2.860±0.792 and 1.940±0.477, respectively).

At a cut depth of 2 cm when contact firing from "Fort 9R", significantly higher ($p<0.01$) values of the indicator were established for BB compared to CF, DF and LB (11.14±0.65, 6.960±1.346, 8.600±0.292 and 9.340±0.713 respectively) as well as significantly lower ($p<0.01$) indicator values for CF compared to DF and LB (6.960±1.346, 8.600±0.292 and 9.340±0.713, respectively); at shots from 25 cm, significantly higher ($p<0.01$) values of the indicator were established for BB compared to CF, DF and LB (5.680±0.807, 3.660±0.546, 2.600±1.468 and 3.080±0.311, respectively) and significantly higher ($p< 0.05$) indicator value for CF compared to LB (3.660±0.546 and 3.080±0.311, respectively).

When shooting from the "Fort 17R" at contact range, significantly higher ($p<0.05$-0.01) indicator values were set for BB or CF compared to DF and LB (8.800±0.612, 7.900±0.815, 6.360±0.770 and 5.720±0.311).

When comparing the values of the indicator when fired from both pistols from different distances, significant ($p<0.05$-0.01) differences were found within all groups except "Fort 9R" at distances of 25-50 cm for CF, DF and LB, as well as "Fort 17R" distances of 25–50 cm for CF and DF.

When comparing the values of the indicator when fired from the "Fort 9R" and "Fort 17R" pistols, significantly ($p<0.05–0.01$) higher values were found when fired from the "Fort 9R" at contact range in BB, DF and LB and DF 50 cm (11.14±0.65 and 8.800±0.612, 8.600±0.292 and 6.360±0.770, 9.340±0.713 and 5.720±0.311, 3.020±0.444 and 1.500±1.056, respectively) and "Fort 17R" when fired from a distance of 25 cm in LB (3.760 ±0.230 and 3.080±0.311, respectively).

At a cut depth of 3 cm when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range (except for BB when fired from the "Fort 9R"). In all groups, except for CF, significantly ($p<0.05$-0.01) higher values of the parameters were recorded with shots from the "Fort 9R" pistol (BB 11.50±0.85 and 8.960±1.155, DF 8.960±0.623 and 5.040±0.586, LB 9.240±0.847 and 1.200±1.286).

At a cut depth of 4 cm, when fired from both the "Fort 9R" and "Fort 17R" pistols, a temporary cavity was formed only when fired at contact range. In all groups, except for CF, significantly ($p<0.05$-0.01) higher values of the parameters were recorded with shots from the "Fort 9R" pistol (BB 10.40±2.78 and 6.240±1.396, DF 6.340±0.493 and 0.600±1.342, LB 6.500±1.277 and 0).

At a cut depth of 5 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB and DF; at the depth of the cut of 6 cm, a temporary cavity was formed only during contact shots from the "Fort 9R" pistol in BB.

In a previous study, when analyzing the penetration depth of ammunition when fired from "Fort 9R" and "Fort 17R" pistols into blocks covered with different types of clothing, we found that cotton fabric has better protective properties when fired from "Fort 9R", and leatherette at shots from "Fort 17R" [7].

In a study conducted using the "Fort-12RM" pistol model on non-biological simulators of a human torso dressed in cotton knitwear, the authors established the largest dimensions of the temporary cavity at a depth of cut from 3 cm to 5 cm, and the peak of the force of the traumatic effect – at a depth of about 4 cm [4].

Such results and data obtained in our study are well consistent with the generally accepted classical theory regarding the formation of a temporary cavity, namely the theory of cavitation of ammunition in the body, when halfway through its journey it conditionally reaches an angle of 90 degrees relative to the wound channel, and then, as it were, "backs up", which causes expansion of the temporary cavity in the center [11] and then narrowing without an exit channel if the energy of the ammunition is insufficient, or causes the formation of an exit wound, which may have

the appearance of a large lacerated wound if the temporary cavity was large at that time [12].

S.A. Rodrigues [9] and co-authors compared the parameters of the temporal cavity when firing into the chest through the ribs using 5.56×45 mm and 7.62×51 mm projectiles. It was established that the use of the latter causes an increase in the size of the temporary cavity.

Conclusions. In most cases, significantly larger parameters of the temporary cavity were obtained when firing from the "Fort 9R" pistol. Taking into account the parameters of the temporary cavity, cotton fabric had the best protective properties when fired from "Fort 9R", and leatherette when fired from "Fort 17R". When firing from both the "Fort 9R" and the "Fort 17R" at close range, the formation of a cavity was noted, which slowly expands and then narrows; when shots were fired from distances of 25 and 50 cm, the formation of a cone-shaped temporary cavity was noted, which decreased with increasing depth.

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