

# Computed Tomography and Cancer Risk: A Systematic Review

## Tomografía computada y riesgo de cáncer: revisión sistemática

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DIANA ISABEL ESPINOZA MORALES

Universidad de Sonora, México

ORCID: <https://orcid.org/0009-0002-2629-1734>

ANTONIO ALVÍDREZ LABRADO

Universidad de Sonora, México

ORCID: <https://orcid.org/0009-0006-2441-4605>

ARACELI ZAZUETA CÁRDENAS

Universidad de Sonora, México

ORCID: <https://orcid.org/0009-0006-4690-1412>

JUAN ANTONIO LUGO MACHADO<sup>a</sup>

Instituto Mexicano del Seguro Social, México

ORCID: <https://orcid.org/0000-0003-4864-8546>

### ABSTRACT

**Introduction:** Computed tomography (CT) is an indispensable diagnostic tool; however, its increasing use has raised concerns about the cancer risk associated with exposure to ionizing radiation. **Objective:** To systematically evaluate the relationship between CT exposure and cancer risk, based on methodologically sound scientific literature. **Methods:** An independent systematic review was conducted following the PRISMA methodology. Databases (PubMed, Scopus and Science Direct) were searched using controlled descriptors. Selection was carried out using the Rayyan program, considering articles published between January 2000 and April 2025. **Results:** A total of 13 studies were selected. Overall, the evidence points to a possible association between exposure to CT and an increased risk of cancer, particularly in pediatric populations, with a pattern suggesting dose dependence. Although some studies did not reach statistical significance, the overall synthesis of data supports a trend that warrants attention, while also recognizing the presence of potential publication bias. **Conclusion:** Exposure to CT, particularly at younger ages, has been linked to a potential increase in cancer risk. In this context, applying the ALARA principle and ensuring the clinical justification of each study are advisable to help reduce potential long-term risks.

### Keywords

X-ray computed tomography; radiation-induced neoplasia; risk; ionizing radiation; systematic review.

<sup>a</sup> Correspondence author: [juan.lugo.imss@gmail.com](mailto:juan.lugo.imss@gmail.com)

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### RESUMEN

**Introducción:** La tomografía computarizada (TC) es una herramienta diagnóstica indispensable; sin embargo, su uso creciente ha suscitado preocupación por el riesgo de cáncer asociado a la exposición a radiación ionizante. **Objetivo:** Evaluar sistemáticamente la relación entre exposición a TC y riesgo de cáncer, basándose en literatura científica de alta solidez metodológica. **Métodos:** Revisión sistemática independiente siguiendo la metodología PRISMA. Se consultaron bases

de datos (PubMed, Scopus y Science Direct) utilizando descriptores controlados. La selección se llevó a cabo mediante el programa Rayyan, considerando artículos publicados entre enero de 2000 y abril de 2025.

**Resultados:** Se seleccionaron 13 estudios. En conjunto, la evidencia apunta a una posible asociación entre la exposición a TC y un mayor riesgo de cáncer, especialmente en población pediátrica, con un patrón que sugiere dependencia de la dosis. Aunque algunos trabajos no alcanzaron significación estadística, la síntesis global de los datos respalda una tendencia que merece atención, reconociendo además la existencia de indicios de sesgo de publicación. **Conclusión:** La exposición a TC, particularmente en edades tempranas, se ha vinculado con un posible aumento en el riesgo de cáncer. En este contexto, resulta recomendable aplicar el principio ALARA y asegurar la adecuada justificación clínica de cada estudio, con el fin de reducir riesgos potenciales a largo plazo.

**Palabras clave**

tomógrafos computarizados por rayos X; neoplasias inducidas por radiación; riesgo; radiación ionizante; revisión sistemática.

## Introduction

Medical imaging using ionizing radiation accounts for approximately 50% of the total radiation exposure in the general population in the United States (1,2). In contrast, in countries like the United Kingdom, this proportion is lower; in 2005, the average annual dose attributable to imaging procedures represented one-sixth of the total exposure (3). Based on extrapolation models derived from survivors of atomic bombings, it is estimated that computed tomography (CT) could be responsible for between 1.5% and 2% of all future cancer cases in the United States (2). This increase is reflected in the average annual exposure per capita, which has shown a steady rise over the past three decades (4). Even in managed care systems, CT use doubled per capita exposure between 1996 and 2010 (5).

It is estimated that nearly 75% of CT scans are performed in acute care settings. In urban hospitals, the frequency of CT requests per patient doubled between 2001 and 2007, with thoracic CT scans increasing sixfold (6). Additionally, in older adults, the rate increased from 204 scans per 1,000 people per year in 2000 to 428 in 2016 (7). While

many of these scans are justified to rule out serious pathologies—such as trauma, pulmonary embolisms, or cerebrovascular events—repeated scans are more common in oncology patients, where the immediate benefit outweighs the long-term risk (8).

Today, CT constitutes half of the medical radiation exposure in the United States (9). Ionizing radiation can damage DNA directly or through free radicals, generating oncogenic mutations (10,11). This damage depends on tissue radiosensitivity, which is higher in organs like bone marrow (12). Risk is estimated based on the linear no-threshold model, which postulates that any dose, no matter how small, results in a proportional increase in risk (13). However, this model is based on data from survivors of Hiroshima and Nagasaki, who were exposed to doses above 100 millisieverts (mSv), so its extrapolation to diagnostic doses is still debated (14).

Since its introduction in the 1970s, CT has revolutionized medical practice, but its doses are much higher than those of other diagnostic techniques. The individual risk may seem low; however, the volume of scans multiplies the population impact (2). In 2007, 72 million CT scans were performed in the United States, with an estimated 29,000 future cases of cancer, especially from abdominal, thoracic, and pelvic scans, with greater impact on women due to the radiosensitivity of the breast and lungs (15). According to the BEIR VII report, an exposure of 10 mSv—equivalent to a CT scan of the neck, chest, abdomen, or pelvis—can induce one case of cancer for every 1,000 people exposed (16). The International Commission on Radiological Protection warned that cumulative exposures from repeated studies reach significant risk levels (16).

Epidemiological studies reinforce this concern. González et al. (17) documented an association between accumulated CT dose and the risk of leukemia and brain tumors in children. Brenner and Hall (18) and Miglioretti et al. (19) estimated that between 1.5% and 2% of cancers could be attributed to CT, particularly when performed without a clear indication. In

childhood, a head CT can cause one additional case of leukemia or brain tumor for every 10,000 scans (20,21). Similarly, CT scans performed in 2007 in the United States were estimated to be responsible for approximately 29,000 future cases (15).

However, some nuances are relevant. Schultz et al. (22) noted that exposures below 100-200 mSv are not consistently associated with a significant increase in cancer risk. In the clinical setting, Hikino et al. (23) concluded that, in trauma patients, the benefit of a cervical CT outweighs the risk when indicated in high-suspicion cases. Meanwhile, Chen et al. (24), in a systematic review of pediatric head and neck CT scans, reported a marginal but significant increase in the risk of malignancy, particularly thyroid cancer (IRR = 1.14; 95% CI: 1.01–1.28).

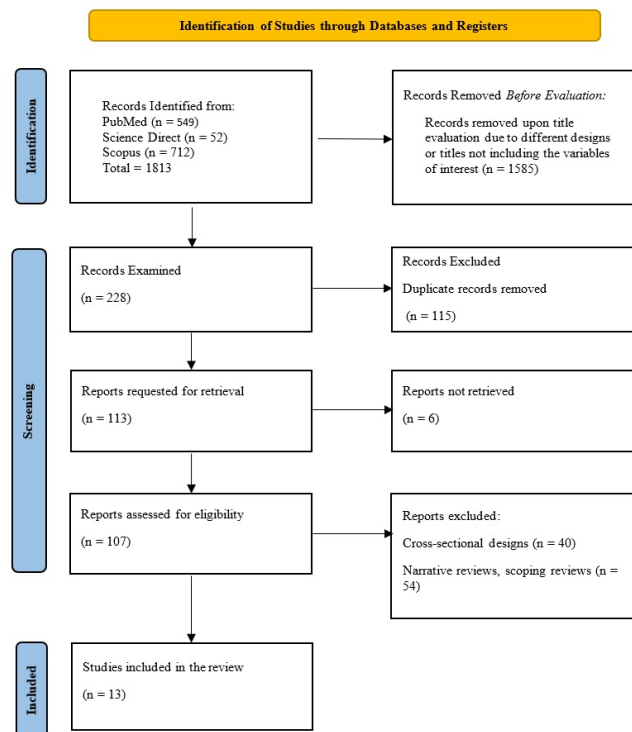
Risk assessments derived from radiation in imaging studies are largely based on extrapolations of data from survivors of the 1945 atomic bombings (14,25). In this article, to identify studies with greater methodological rigor that support the link between CT exposure and cancer risk, a critical review of the scientific literature was conducted.

## Methods

Two researchers independently conducted a systematic review following the PRISMA guidelines (26,27) with the aim of evaluating the relationship between CT use and cancer risk. Their search focused on the databases PubMed, Scopus, and ScienceDirect, using the following combinations of keywords: in PubMed (“Computed tomography” AND “cancer risks”), in Scopus (“computed” AND “tomography” AND “cancer” AND “risk” AND “systematic” AND “review”), and in ScienceDirect (“computed” AND “tomography” AND “cancer” AND “risk” AND “systematic” AND “review”). Rayyan software was used for article management and selection (28,29).

The literature search (January 2000-April 2025) included English-language articles with full and free access that were systematic reviews

or cohort studies on the relationship between CT and cancer risk (Figure 1). Publications in other languages and different study designs, such as editorials, narrative reviews, or scoping reviews, were excluded. Methodological quality was assessed using AMSTAR2 for systematic reviews and the Newcastle-Ottawa Scale for cohort studies (30,31); the Newcastle-Ottawa Scale was applied to cohort studies (32,33).



**Figure 1.**  
PRISMA Methodology for the systematic review on computed tomography and cancer risk.

## Results

The analysis of the reviewed studies shows convergent evidence of an association *between exposure to diagnostic CT radiation and an increased risk of cancer in both pediatric and adult populations*. However, the magnitude and statistical significance of this association vary depending on the type of study, methodological

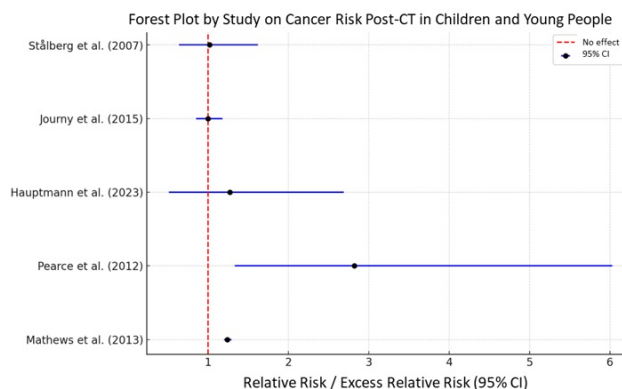
design, anatomical location irradiated, and the accumulated dose received.

In the pediatric population, Mathews et al. (34), in an Australian cohort of over 680,000 individuals, identified a 24% increase in cancer incidence among those exposed to CT during childhood or adolescence (IRR = 1.24; 95% CI: 1.20-1.29), with a clear dose-response relationship. Similarly, Pearce et al. (21) found that an accumulated dose of 50-74 mGy was associated with a relative risk of 2.82 for brain tumors (95% CI: 1.33-6.03) and 3.18 for leukemia (95% CI: 1.46-6.94), which represents nearly triple the risk compared to the unexposed group. Complementarily, the European multicenter study EPI-CT, led by Hauptmann et al. (35), reported an excess relative risk (ERR) of 1.27 (95% CI: 0.51-2.69) per 100 mGy accumulated, especially for gliomas. This further reinforces a significant dose-dependent relationship.

Other focused studies also revealed positive associations. For instance, Chen et al. (24) reported an IRR of 1.14 (95% CI: 1.01-1.28) after head/neck CT in children and highlighted the radiosensitivity of these regions. In the specific context of thyroid cancer, Han et al. (36) found a combined OR of 1.52 (95% CI: 1.13-2.04), higher after exposures to dental X-rays and neck CT scans. Likewise, Huang et al. (37), in a meta-analysis with over a million children, reported a relative risk (RR) of 1.54 (95% CI: 0.84-2.45) for brain cancer, with a rising trend in risk as the dose received increased.

In the adult population, the risks appear to increase with the accumulation of diagnostic studies. Cao et al. (38) found a combined odds ratio (OR) of 5.89 (95% CI: 3.46-10.35), and for higher exposures, an OR as high as 33.31 (95% CI: 21.33-52.02), suggesting a drastic increase in risk in lifetime risk attribution models. In another study focused on individuals under 22 years of age, Abalo et al. (39) estimated an ERR of 9.1 per gray for brain tumors (95% CI: 5.2-13.1) and 26.9 per gray for leukemia (95% CI: 2.7-57.1). This confirms a high dose-dependent risk in the pediatric population.

However, some studies took more conservative stances. Marcu et al. (40) found an OR of 1.17 (95% CI: 0.89-1.55) without statistical significance, but emphasized the relevance of long-term follow-up and monitoring of accumulated doses. On the other hand, Mack (41) questioned the linear no-threshold model and reported an OR of 0.90 (95% CI: 0.70-1.15), consistent with a neutral or even protective effect. Similarly, Ståhlberg et al. (42) found no significant association between prenatal X-rays and childhood brain tumors (OR: 1.02; 95% CI: 0.64-1.62). Finally, Journy et al. (43), after adjusting for predispositional factors such as genetic syndromes, found an adjusted RR of 1.00 (95% CI: 0.85-1.18), suggesting that, in the absence of proper adjustments, risks might be overestimated due to indication bias (Figure 2).



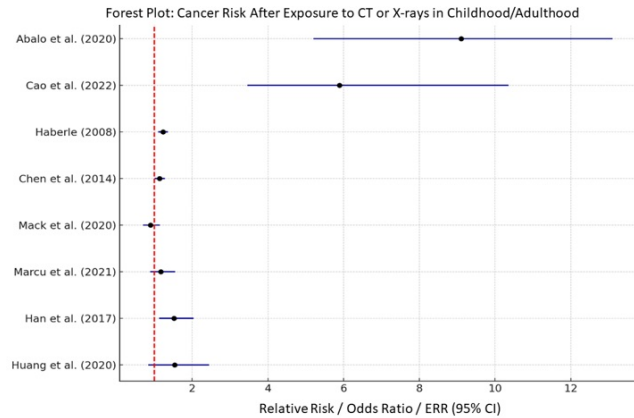
**Figure 2.**  
Synthesis of Data from Articles on the Risk of Cancer Post-Computed Tomography in Children and Young People

Figure 2 shows that most studies support a positive association between early-age CT exposure and an increased risk of cancer. For example, Mathews et al. (34) reported an IRR of 1.24 (95% CI: 1.20-1.29), equivalent to a 24% increase in incidence. Pearce et al. (21) found a RR of 2.82 (95% CI: 1.33-6.03) for brain tumors in children with accumulated doses of 50-74 mGy, nearly tripling the risk compared to unexposed individuals. Hauptmann et al. (35) reported an ERR of 1.27 (95% CI: 0.51-2.69) for every 100 mGy accumulated, supporting a linear

dose-response relationship between CT exposure and cancer (35).

In contrast, Journy et al. (43) did not find a significant increase in risk (RR: 1.00; 95% CI: 0.85-1.18), suggesting that controlling for predispositional factors and indication bias could explain the previous associations (44). Similarly, Ståhlberg et al. (42), in analyzing prenatal exposure to abdominal X-rays, reported an OR of 1.02 (95% CI: 0.64-1.62), with no evidence of increased risk.

The comparative analysis shows considerable heterogeneity in cancer risk estimates from CT (Figure 3). Overall, the evidence suggests an increased risk, with variations depending on the population and methodology. In children, Huang et al. (37) reported a RR of 1.54 (95% CI: 0.84-2.45) for brain cancer, without significance, while Han et al. (36) found a significant OR of 1.52 (95% CI: 1.13-2.04) for the thyroid region. Chen et al. (24) described an increase following head and neck CT (IRR = 1.14; 95% CI: 1.01-1.28), and Abalo et al. (39) calculated an ERR of 9.10 per gray (95% CI: 5.2-13.1), confirming the dose-response relationship. Haberle (44) estimated a RR of 1.23 in radiosensitive organs. In adults, Marcu et al. (40) found a RR of 1.17 (95% CI: 0.89-1.55), while Cao et al. (38) reported an OR of 5.89 (95% CI: 3.46-10.35) in multiple exposures. In contrast, Mack (41) questioned the linear extrapolation and reported an OR of 0.90 (95% CI: 0.70-1.15), without significance.



**Figure 3.**  
Synthesis of Data from Articles on Cancer Risk After Exposure to Computed Tomography or X-rays in Childhood/Adulthood

## Discussion

The findings of this systematic review reinforce the existing evidence regarding the increased cancer risk associated with exposure to ionizing radiation from CT scans, particularly in pediatric populations. This trend is reflected in key studies included in the analysis, such as those by Mathews et al. (21) and Pearce et al. (34), which show statistically significant associations between accumulated radiation doses and higher incidences of leukemia and brain tumors in children and adolescents.

These findings are supported by Bernier et al. (45), who synthesized three large pediatric cohorts (from the UK, Australia, and Taiwan) with consistent results regarding the dose-response relationship between CT and cancer occurrence. Although the Taiwanese study did not observe a significant increase in malignant cancers, it did identify an elevation in benign brain tumors, thereby highlighting the possible underestimation of risk in certain contexts due to diagnostic biases or the lack of adjustment for comorbidities.

On the other hand, the results of the present review also align with recent projections from Smith-Bindman et al. (5), who estimate that if current CT usage patterns in the United

States continue, approximately 103,000 new cancer cases could be attributed to these scans in a single year. Their analysis emphasizes the relevance of cumulative risk in adults due to the high volume of studies, despite the fact that the risk per examination is higher in children. The highest estimates are related to abdominal, pelvic, and thoracic CT scans, which corresponds with the findings of our review regarding the most irradiated anatomical locations.

Complementarily, Gibson et al. (46) provide an Australian population-based perspective that not only demonstrates the progressive increase in CT usage but also the disproportionate risk among women and young adults, who exhibit greater biological susceptibility to radiation damage. This study identifies that 61% of cancers attributed to CT were in women, and that young adults (15-44 years old) accounted for 37% of incident cancer cases, despite representing only 26% of the total scans performed.

This evidence is further supported by the recent work of Azman et al. (47), who propose a protocol for systematic reviews and meta-analyses focused on repeated CT scans in pediatric populations and their relationship with cancer risk. The protocol highlights that factors such as positioning errors, low image quality, and poor data transfer contribute to unnecessary repetitions. It also identifies that adolescent girls, obese patients, and those undergoing multi-phase studies receive higher effective doses. This review aims to quantify the repetition rate, accumulated doses, and the most common types of cancer in these patients, which could complement future updates to the present analysis.

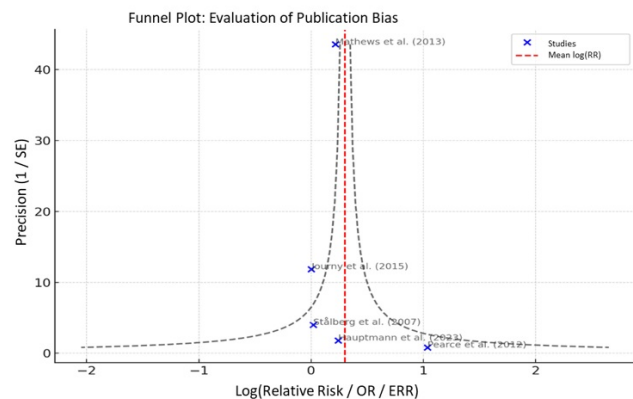
When comparing these results across studies, a concerning pattern emerges: while CT is a crucial diagnostic tool, its use without clear clinical justification may lead to a significant burden of radiation-induced cancers, particularly if strategies for dose optimization, diagnostic justification, and monitoring in vulnerable populations are not adequately applied.

Furthermore, the heterogeneity in methodological designs and specific organ dose estimates across the reviewed studies underscores the need to unify diagnostic criteria and

international radiological protection protocols. While individual risks may seem low, the population-wide magnitude of its use makes CT a significant public health concern.

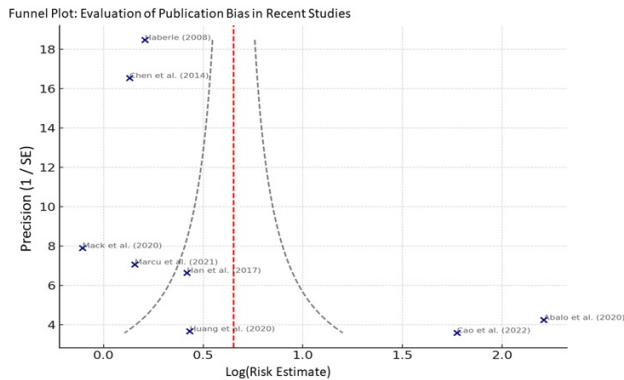
### Formal Analysis of Publication Bias

The formal evaluation of publication bias using Egger's test showed significant asymmetry (intercept -0.163;  $p = 0.018$ ), while the Duval & Tweedie method estimated the absence of three studies required to achieve symmetry in Figure 4. These results suggest a potential overestimation of the risk associated with CT exposure due to the underrepresentation of studies with null or negative findings.



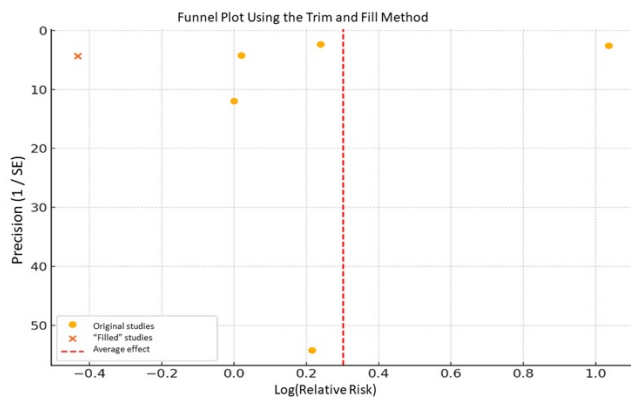
**Figure 4.**  
Publication Bias Analysis of Cohort Studies

Figure 5 showed moderate asymmetry, with a predominance of studies reporting increased risk ( $RR > 1$ ) and a limited presence of null results, suggesting a possible publication bias. Although this is not a formal test, this finding indicates that studies with positive associations between CT and cancer are more likely to be published. Additional tests such as Egger's or trim-and-fill would be useful to confirm this.



**Figure 5.**  
Publication Bias Analysis of Systematic Reviews

Figure 5 shows asymmetry consistent with publication bias, as less precise studies tend to report higher risks, and there is an absence of studies with null or negative results on the left side of the funnel. Figure 6 shows a funnel plot corrected using the Duval & Tweedie method, where the addition of three simulated studies helped compensate for the initial asymmetry and reveal the presence of publication bias.



**Figure 6**  
Funnel Plot Corrected with the Duval & Tweedie Method  
(Trim-and-Fill)

## Conclusion

The available evidence suggests that CT, particularly in childhood and adolescence,

may be associated with a modest risk of cancer, particularly brain tumors and leukemia. Although the individual risk is low, the growing use of this technique poses a public health challenge. The relationship appears to depend on accumulated dose and methodological factors, so the findings must be interpreted with caution. Therefore, it is essential to apply the ALARA principle, clinically justify each study, consider non-radiation alternatives, and promote higher-quality prospective research to strengthen the evidence.

## Limitations and Considerations

The main limitations of this review include the methodological heterogeneity of the studies, which complicates a homogeneous quantitative synthesis, and the potential publication bias evidenced in the funnel plot. The lack of individualized dose estimates and insufficient adjustment for comorbidities or predispositional factors may have overestimated the risk. Additionally, limited follow-ups do not always capture the latency of radiation-induced cancer. Finally, the restriction to English-language articles and freely accessible sources, along with the use of extrapolated models from different populations, reduces the generalizability of the findings.

## Clinical Implications and Recommendations

This review highlights the need to carefully justify the indication for CT, especially in children and young people, optimizing dose protocols and prioritizing, when possible, non-ionizing alternative techniques. Strict application of the ALARA principle is recommended, as well as strengthening training for staff on dose reduction and creating electronic records to document accumulated exposure. Furthermore, the promotion of multicenter prospective studies, the encouragement of publishing neutral results to reduce biases, and the updating of clinical guidelines that integrate radiation risk assessment are recommended, alongside

fostering patient and family education and informed participation.

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