entry and use of biosimilars could lead to vast savings of health-care resources. Most health-care systems suffer from substantial financial constraints, and such savings could be redistributed to provide other health-care services. Although the increased convenience from subcutaneous immunotherapy is real, we would argue that it is outweighed by the long-term cost of suboptimal biosimilar adoption. We propose that payers and providers around the globe reconsider the use of subcutaneous immunotherapy, taking into account the additional costs associated with these formulations compared with potential intravenous biosimilar versions.

Contributors

All authors were involved in the design, initial drafting, and subsequent editing of the manuscript, and had final responsibility for the decision to submit for publication.

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Essay

Abdominal shielding not recommended for diagnostic imaging with ionising radiation during pregnancy

In part due to its rare occurrence, cancer during pregnancy poses unique challenges that require careful consideration of both maternal and fetal health. For the best possible outcome for both mother and child, management during pregnancy should closely follow established guidelines.[1] Oncological staging is necessary to identify optimal personalised treatment plans for each patient, and should be performed in the same manner as for patients who are not pregnant. However, selecting appropriate imaging methods, especially among those that use ionising radiation, requires a careful balance between maternal benefits and fetal risks. This challenge complicates standardisation of diagnostic approaches and harbours the risk of underusing diagnostic imaging, potentially

resulting in suboptimal diagnostic and therapeutic management of pregnant individuals with cancer. This consideration applies to all diagnostic imaging during pregnancy, not only in an oncological setting. A careful balance is needed to ensure fetal and maternal safety while obtaining an accurate diagnosis.

Due to potential adverse effects on the fetus, exposure to ionising radiation should be avoided as much as possible during pregnancy. Cumulative fetal radiation exposure above the threshold of 100 milligray should be avoided, as exceeding this limit has been associated with the potential onset of a decrease in intelligence quotient or deterministic (tissue) effects, including fetal demise, growth disturbances, and congenital malformations.[2,3] An additional risk factor is radiation-induced childhood cancer, for which the probability of the effect is related to the effective dose of the fetus. Therefore, all studies during pregnancy should adhere to the as-low-as-reasonably-achievable principle, and non-ionising imaging procedures, such as ultrasound and MRI, are the preferred techniques for staging during pregnancy.[2] However, ionising imaging techniques should not be withheld when necessary to ensure accurate diagnostics, especially for oncological or other life-threatening conditions.[4]

In the 1950s, gonadal and fetal lead shielding was recommended by the International Commission on Radiological Protection to reduce the possible harms of ionising radiation.[5] Despite many advances in imaging technology and radiation dose reduction, this practice has become deeply ingrained in the daily routines of many practitioners, and the question of abdominal shielding frequently comes up with patients who are pregnant. Patient contact shields remain a common feature in several radiology departments.[6] Clinicians are not always aware of the limitations of patient shielding during pregnancy. When oncologists and other health-care providers endorse shielding, patients might become puzzled if radiologists present contradictory recommendations.

Since 2012, studies have emerged that challenge this continued use of fetal shielding,[7,8] and several organisations have recommended discontinuing routine use of gonadal and fetal shielding in diagnostic x-ray examinations. The American Association of Physicists in Medicine (AAPM) issued a position statement advocating this change in 2019, followed by the British Institute of Radiology in 2020, and a European consensus guideline in 2022.[9–11] The Advisory Board on Cancer, Infertility, and Pregnancy also endorses this statement with multiple factors supporting the recommendation.[12]

For the **Advisory Board on Cancer, Infertility, and Pregnancy** see www.ab-cip.org

In the past few decades, advancements in diagnostic imaging technology have produced x-ray tubes with very little radiation leakage and much better x-ray detectors, creating images with reduced patient radiation doses and even better diagnostic quality than before, thereby reducing the potential benefit of shielding. Notably, all current ionising radiation imaging techniques result in fetal exposures below 50 millisievert—a level not associated with increased risk of tissue damage.[2] Imaging departments should be involved in programmes that monitor routinely used exposure levels. Abdominal shielding aims to prevent the primary beam reaching the patient. Shielding cannot prevent internal scatter, which constitutes the majority of radiation exposure to the fetus.[9] Studies from 2015 onwards have shown that use of abdominal shielding can increase the effective radiation dose to both the mother and the fetus.[7,8] This increased fetal dose arises in part from the deflection of internal scatter and the generation of backscatter, which would otherwise dissipate and escape the maternal body when shielding is not used.[13] This principle applies for both projectional radiography and CT because the direction of the primary beam, along with the rotation of the x-ray tube and detector in CT, result in radiation travelling through various angles and directions.

More importantly, the use of abdominal shielding can interfere with the automatic exposure control of the imaging system. Indeed, CT scans automatically adapt the radiation dose to the density of the studied portion of the body. The presence of shielding in the imaging field of view can drastically increase x-ray output, resulting in an increase in the patients' radiation dose, and in turn, an increase in fetal irradiation (up to a doubling). Good practice consists of starting a CT investigation with a (lead-free) full scout view that is then the basis for an appropriate automatic exposure control setting. Omitting the scout view at the fetal level might result in missing crucial information, potentially causing the scanner to increase the radiation dose to prevent suboptimal image quality. Routinely used, preprogrammed settings of the automatic exposure control should be used during pregnancy, as modifying the setting might result in lower-quality imaging. In addition, shielding placed inside the imaging field of view or shielding that moves into the imaging field of view can obscure important anatomy or pathology by introducing artifacts, resulting in lower imaging quality, thus requiring additional or repeat examinations and associated cumulative radiation exposure. In the figure, a typical x-ray exposure has been simulated for a chest–upper abdomen x-ray examination of a patient who is pregnant. The absorbed dose at the level of the fetus is less than 1:1000 of the absorbed radiation dose in the primary beam, and therefore typical effective doses are less than 50 microsievert. Dose decreases rapidly with distance from the primary beam. Careful collimation of the primary beam is therefore the first priority. Furthermore, prioritising non-irradiating techniques whenever possible over irradiating methods such as CT and PET–CT is advisable.

These recommendations do not necessarily apply to radiotherapy, in which other particles and very different

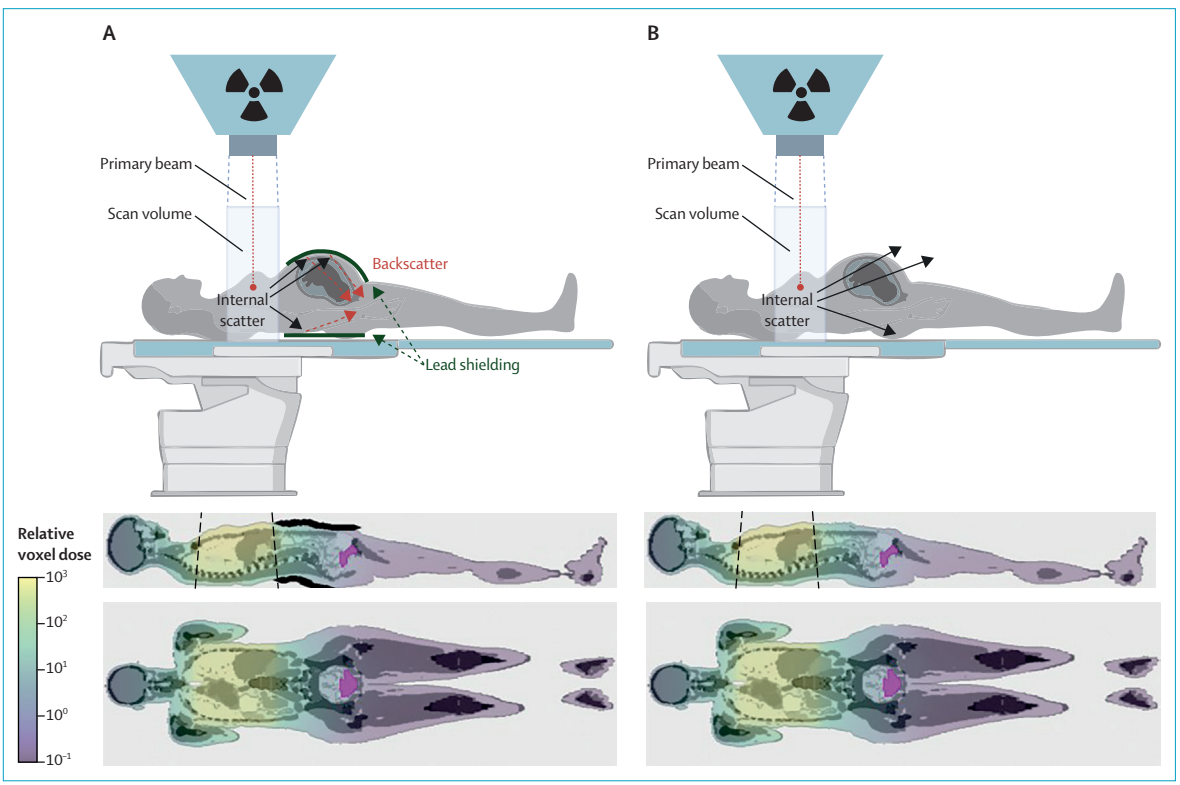

***Figure*: Dose distributions obtained from Monte Carlo simulations for a typical x-ray exposure for a chest—upper abdomen x-ray examination of an anthropomorphic phantom representing a pregnant individual (approximately 0–4 weeks of gestation)**
The dose distributions are presented with lead shielding (A) and without lead shielding (B). The dose values were normalised to the average dose in the uterus (shown in pink) without lead shielding. The doses scored in the uterus are between 100-times and 1000-times lower than the doses recorded in the region of the primary beam, for both cases with and without the additional lead protection.

geometries can be used alongside primary beams that are shaped to optimise dose delivery at the cancer while sparing the organs at risk. Fetal dose during external beam radiotherapy is primarily due to leakage radiation from the linear accelerator head and scatter from the collimators, filters, and other objects. This makes the use of fetal shielding—consisting of bridge shields, table-mounted shields, or mobile shields in accordance with the AAPM—recommended. Studies have shown that a 5 cm-thick lead shield can effectively reduce fetal effective doses to below 0·1 sievert when treating tumours located above the fetus. Additionally, careful planning of treatment fields and limiting exposure time are crucial to further minimising fetal dose, emphasising the importance of tailored strategies to balance effective maternal treatment with fetal safety.[14,15]

In conclusion, whenever ionising imaging techniques are used during pregnancy, adherence to the as-low-as-reasonably-achievable principle is essential to minimise risk associated with ionising radiation. Before imaging, fetal dose calculations should be performed to assess potential risks; medical radiation physicists play a crucial role in this process, ensuring the appropriate optimisation of CT dose settings. With the current available evidence, abdominal shielding for diagnostic imaging in pregnancy should be discontinued as a routine practice. This knowledge has already begun to circulate within the radiological community.[16,17] However, persistent uncertainties about the use of abdominal shielding remain prevalent in clinical practice, as evidenced through our work with the Advisory Board on Cancer, Infertility, and Pregnancy. We must intensify efforts to raise awareness among all health-care professionals involved in the care of patients who are pregnant. Achieving widespread adoption of this updated practice necessitates proactive engagement not only from radiologists but also from obstetricians, oncologists, and all referring physicians who hold key responsibilities in counselling and guiding patients through complex diagnostic and therapeutic decisions.

Contributors
FA conceptualised this Essay. RTM and CLL were responsible for the visualisation. CLL wrote the original draft manuscript. SN, RTM, PJ, CB, HB, CS, FEL, PH, KVC, VV, and FA reviewed and edited the manuscript.

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