Archives of Academic Emergency Medicine. 2022; 10(1): e39

REVIEW ARTICLE

Orthopedic Trauma During Pregnancy; a Narrative Review

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Received: March 2022; Accepted: April 2022; Published online: 18 May 2022

Abstract: **Introduction:** Blunt traumas, like road accidents and falls, are common causes of injuries to pregnant women, and the major risk factors are young age and low socioeconomic level. Due to physiological and anatomical changes specific to pregnancy, such as changes in blood pressure and hemoglobin drop, trauma management involves certain complexities. Physical trauma is estimated to cause at least 1 complication in every 12 pregnancies. This study aims to evaluate orthopedic trauma during pregnancy and appreciate the different approaches to circumvent the resultant challenges. **Methods:** We reviewed 55 articles, published on orthopedic trauma during pregnancy between 2011 and 2021. The articles were identified by searching PubMed, google-scholar, Scopus, and Science-Direct. We utilized the search terms: fall in pregnancy, traumas in pregnancy, motor vehicle accident/crash in pregnancy, blunt trauma in pregnancy, pregnant trauma patient, penetrating injury during pregnancy, assault, interpersonal violence in pregnancy, and mortality and pregnancy. **Results:** According to available reports, after stabilizing the pregnant patient, diagnostic procedures, including radiography, and even gadolinium-based techniques when needed, can be performed to examine extensive trauma. In contrast to elective orthopedic surgery, emergency orthopedic surgeries, including reduction of open fractures, should be performed promptly. **Conclusion:** Based on our investigation, pregnant women with orthopedic injuries that are severe, or even seemingly less severe, experience significantly increased adverse pregnancy outcomes, which include preterm birth, placental abruption, poor infant condition at birth, infant death, and even maternal death.

Keywords: Orthopedic Procedures; Wounds and Injuries; Pregnancy

Cite this article as: Jafari Kafiabadi M, Sabaghzadeh A, Khabiri SS, Sadighi M, Mehrvar M, Biglari F, Ebrahimpour A. Orthopedic Trauma During Pregnancy; a Narrative Review. Arch Acad Emerg Med. 2022; 10(1): e39. https://doi.org/10.22037/aaem.v10i1.1573.

1. Introduction

Trauma is referred to as an externally triggered injury and is one of the major non-obstetric reasons leading to death during pregnancy (1). In orthopedic medicine, trauma or orthopedic trauma is characterized as a serious injury to the parts of the locomotor or musculoskeletal system (2). Physical trauma is estimated to complicate 1 in every 12 pregnancies (3). The most familiar triggers of trauma in pregnancy comprise car accidents, falls, and violent assaults (4). Life-threatening maternal trauma is associated with a 40% to 50% fetal loss, implying that both mother and fetus are at risk (1). Therefore, caring for the obstetric patient who suffers a traumatic injury is one of the most challenging scenarios for both nursing and medical staff.

Physiological changes in pregnancy might have an enormous effect on diagnosis and treatment. For example, circulating blood volume increases from the 6th week of gestation and peaks at approximately the 32nd week. Hence, during resuscitation, it can take up to 50% more volume to cause changes in hemodynamic status (5).

Managing pregnant patients with orthopedic trauma poses challenges that should be carefully considered to protect both the mother and the developing infant. Physiological changes during pregnancy, risk of radiations, and recommendations for monitoring should be focused on during the perioperative and intraoperative processes. In this article,

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we focused on the epidemiology and risk factors of trauma during pregnancy and its management. We reviewed 55 articles published on orthopedic trauma during pregnancy in English language, between 2011 and 2021. The articles were identified by searching PubMed, google-scholar, ScienceDirect, and Scopus. The following keywords were applied: trauma in pregnancy, blunt trauma in pregnancy, penetrating injury during pregnancy, motor vehicle accident/crash in pregnancy, fall in pregnancy, assault, interpersonal violence in pregnancy, pregnant trauma patient, and mortality and pregnancy.

1.1. Epidemiology and risk factors

Blunt trauma is the main cause of injuries among pregnant women. In a study conducted in Pakistan in 2019 (6), road traffic accidents (RTA) were the most common mechanism of injury (47.9%), followed by falls (31.3%). In an alternative research carried out in the United Kingdom in 2016, vehicular collision and interpersonal violence were increasing causes of injury (7). In an Iranian study in 2012 (8), falling (28.1%) was the most prevalent cause of injury, followed by RTA (21.9%). A study conducted in America in 2011, showed that the prevalence of interpersonal violence (IPV) during pregnancy spans between 1-20%, with the domestic partner being the abuser in most cases (9).

Based on the literature, risk factors for maternal trauma include: young age (<25 y) and low socioeconomic status (10), domestic violence (11), noncompliance with proper seat belt use (12), and minimal or no prenatal care in the first trimester (13). On another note, falls come second among the major causes of trauma during pregnancy (8). It was reported that women aged 30 years and below have a twofold risk of falling in pregnancy than those more than 30 years of age (14). The increase in lumbar lordosis in pregnancy moves the center of gravity forward and engenders a higher occurrence of falls. Consequently, violent prodigious exertion should be abhorred in late-stage pregnancy (15).

Voluntary or aggressive trauma is responsible for almost 16% of traumatic lesions experienced by pregnant women (16). The occurrence of home or intimate partner abuse upsurges during pregnancy and is accumulated in the third trimester (17). Depending on the region or the country, these traumas may vary in their rate.

1.2. Maternal physiologic changes

During pregnancy, the body undergoes many physiological and anatomical changes to adapt to the growing fetus. In the second trimester, blood pressure changes between 5–10mmHg below baseline (18), and pulse increases by 5-15bpm (19). Hemoglobin concentration in pregnancy could fall by 5g/L due to plasma volume expansion (20), and the blood volume could increase to approximately 6L. Leukocytosis and erythrocyte sedimentation rates are unreliable diagnostic markers in pregnant patients (21). Besides, there is a drop in the lymphocyte count during pregnancy within the first and second trimesters and a rise within the third trimester (22). Clotting factors and fibrinogen levels also increase. An increase in the clotting factors and fibrinogen results in a hypercoagulable state that is linked to a high vulnerability to thromboembolic complications (23).

Transient osteoporosis may prevail due to the altered physiology of pregnancy (24), increasing a patient's susceptibility to fractures (25, 26). Significant alterations in the anatomy during pregnancy principally result from the gravid uterus. Hypertrophied pelvic vasculature creates the potential for massive retroperitoneal hemorrhage in the event of a pelvic fracture. Uterine compression on the inferior vena-cava results in potential impairment of cardiac output, dropping to 30% during supine positioning (4). In Table-1 common risks and physiological changes during pregnancy are categorized based on time.

1.3. Evaluation and initial management

On presentation to the emergency room, pregnant women with trauma should be stabilized and be assessed based on the severity of the trauma. If the fetus is viable (≥ 23 weeks), fetal heart rate auscultation and fetal monitoring should be performed before obstetrical consultation (15). To assess a pregnant trauma patient, a focused history should be obtained clarifying the origin of the injury. Maternal last menstrual period (LMP), fetal movements, uterine contractions, and vaginal bleeding, are additional factors that should be kept in mind (15). This preliminary evaluation should be done within one minute and basic life-saving measures of trauma should be started simultaneously with the initial assessment. If conventional uninterrupted fetal observation is inaccessible, sporadic Doppler measurement or bedside ultrasound calculation of a fetal heart rate is an appropriate temporary substitute. Maternal status and stability take precedence over the fetal condition. First and foremost, basic life-sustaining measures through rapid assessment of the initial "A-B-Cs" must be performed (27).

1.4. Airway

Airway management and intubation in pregnant patients come with more challenges than unpregnant patients. Pregnant trauma patients with a nonsecure trachea are more vulnerable to aspirate their gastric contents (15). One maternal trachea investigation performed at 12 and 38 weeks of gestation revealed that the percentage of Mallampati class 4 airways (having just visible hard palate and no sight of the soft palate or uvula) was elevated by 34% between the two periods (28). In this regard, video laryngoscopy utilization, if accessible, is paramount because it allows for the maximization of

first-pass success in these intubations.

1.5. Breathing

The marked increase in basal oxygen expenditure and utmost sensitivity of the fetus to maternal hypoxia indicate that oxygen supplementation through a nasal cannula, mask, or endotracheal tube should be performed for every pregnant trauma patient to sustain the oxygen saturation greater than 95% (15). Considering the shift in the diaphragm due to pregnancy, it may be worthwhile to perform a thoracostomy tube insertion 1 to 2 intercostal spaces above normal when needed (28).

1.6. Circulation

In the event of continuous hemodynamic compromise, transfusion of typed and crossed blood is preferred to crystalloid solutions (29). In an emergency setting, however, type O Rh-negative blood is utilized to prevent Rh sensitization unless the mother is in an imminent life-threatening situation (29). Precautions must be observed to prevent supine hypotension post-mid-pregnancy in the injured pregnant patient. This is achievable either by positioning the patient in the left lateral position or by manual uterine displacement, while the traumatized patient is kept in the supine position. In pregnant patients who are not hemodynamically stable, a focused assessment with sonography for trauma (FAST) examination should be performed during the primary survey to assess for possible sources of bleeding. However, FAST cannot detect retroperitoneal hemorrhage, which is more likely in pregnant women because of the increased blood flow to the uterus (28). Any patient with a viable fetus beyond 23 weeks' gestation should have cardiotocographic monitoring. We might consider emergent cesarean section in seriously ill trauma patients after 24 weeks' gestation if the fetus shows non-reassuring heart rhythm.

1.7. Laboratory Tests

Normally, indicated diagnostic tests are analogous to those of non-pregnant patients. Along with conventional trauma laboratory procedures, a type and screen, coagulation profile, fibrinogen, and Kleihauer-Betke (KB) test should be obtained. Fetal-maternal hemorrhage can occur in up to 30% of pregnant patients. Hence, the American College of Obstetricians and Gynecologists (ACOG) guidelines prescribe KB testing for all Rh-negative pregnant trauma patients due to concerns of possible alloimmunization from 4 weeks of pregnancy (4, 30). White blood count during pregnancy is usually elevated and leukocytosis should be monitored through other clinical tests. D-dimer is often positive during pregnancy; therefore, it is not recommended to rule-out venous thromboembolism (15).

1.8. Diagnostic Imaging

Radiographic studies are recommended in indicated conditions and even gadolinium-based contrast agents are used when advantage to the mother overshadows probable fetal risks (15). This is essential to avoid non-obstetrical laparotomy given that non-obstetrical laparotomy alone catalyzes a 26% prevalence of preterm labor during the second trimester and an 82% occurrence of preterm labor in the third trimester (31). When life or limb-threatening injuries are suspected, indicated imaging should not be postponed or forsaken due to apprehensions regarding fetal radiation (4). The highest teratogenicity of ionizing radiation occurs during organogenesis (5-10 weeks). Above 10 weeks, radiation will most probably impair growth or engender CNS effects instead of teratogenic changes (15). Nonetheless, fetuses are improbably affected by radiation beyond 15 weeks of gestation (32). Table-2 elucidates the fetal radiation dose from standard radiography and CT examinations.

Conventional chest radiographic reports in a pregnant female encompass a widened mediastinum, mild cardiomegaly, elevated diaphragms, and protrusion of the pulmonary vasculature. The pelvic X-ray reveals a widening of the symphysis pubis and sacroiliac joints (33).

83 pregnant and 167 non-pregnant patients were scrutinized in a previous chart review at an urban level 1 trauma center. The average number of initial imaging studies was 4.3 in the pregnant patients versus 6.8 in the non-pregnant group. The study showed that blunt injured pregnant trauma victims got remarkably lesser radiographic images during their consultation than their non-pregnant counterparts. However, only 1% of those pregnant patients were diagnosed with a delayed injury (34).

When feasible, body CT investigations of pregnant trauma victims should be done with intravenous iodinated contrast. Iodinated contrast implementation enhances the recognition of both maternal and fetal injuries by imparting vascular contrast in organs and opacification of vascular structures, as well as the placenta (31). Intravenous iodinated contrast material (ICM) is designated as a category B drug by the U.S. Food and Drug Administration (FDA). This implies that it has not demonstrated any side effects in neither animal nor human studies. It is more desirable to utilize ICM to acquire a single diagnostic CT study rather than performing a non-enhanced CT study that may be undiagnostic and compels a repeat study.

MRI implementation in pregnancy may be beneficial since no fetal-related deleterious consequences have been reported following its application. Even though the FDA has not validated the assurance and application of MRI yet, no existing records relating to adverse perinatal outcomes or long-term pediatric outcomes due to the employment of MRI

Table 1: Common risks and physiologic changes during pregnancy categorized based on trimesters

Trimester	Physiologic Changes	Risk Factors
First	- Central nervous system development - Increased white blood cell count - Increased erythrocyte sedimentation rate	-Radiosensitive development period -Increased risk of teratogenesis -Hypercoagulable state -Increased risk of abortion with general anesthesia
Second	- Relatively radio resistant fetal central nervous system - Increased white blood cell count - Increased erythrocyte sedimentation rate	-Increased risk of supine aortocaval compression -Hypercoagulable state -Increased risk of abortion with general anesthesia -Increased risk of seat belt-related injury to the fetus
Third	- Maternal blood volume increased by 40%–50% - Increased white blood cell count - Increased erythrocyte sedimentation rate	-Increased risk of supine aortocaval compression -Increased risk of pregnancy-related osteoporosis -Increased risk of seat belt-related injury to the fetus

in pregnancy prevail. At present, gadolinium utilization in pregnancy is contentious. In rare cases, contact with gadolinium led to both pediatric and adult nephrogenic systemic fibrotic syndrome in renal insufficient patients (4). Based on the standard procedure, imaging of pregnant trauma patients should replicate those of any other patient undergoing conventional radiography, CT, and MR imaging (31).

1.9. Definitive treatment

After the initial assessment and once the maternal hemodynamic balance is attained, monitoring the fetus should immediately commence.

Surgical supervision of a pregnant patient should consume the barest minimum time possible to attenuate perioperative difficulties (35). All indicated emergent injuries such as open fractures, life-threatening traumas, or fissures linked to vascular injury should be treated, regardless of the pregnancy status. Elective orthopedic surgery procedures should be postponed to the postpartum period to avoid injury to the fetus (1).

Maternal pelvic fractures are the most common cause of fetal death amongst traumatic injuries (36). When taken in isolation, pelvic fractures do not warrant emergency cesarean section, as delivery through the vagina can be performed safely, even in the third trimester (37). Pelvic fractures present a challenge because of the proximity to the uterus and the possibility of massive uterine hemorrhage and placental abruption (36). If severe bleeding from a uterine region occurs, an emergency hysterectomy should be done (1).

In a pregnant trauma patient having a viable fetus, who does not respond to cardiopulmonary resuscitation or has a non-survivable injury, a perimortem cesarean section should be contemplated (4). A perimortem cesarean section should be considered, for maternal and fetal benefits, within 5 minutes of maternal hemodynamic instability with failure of resuscitation (38).

1.10. Preoperative considerations

Pregnant patients are at higher risk of aspiration (39), due to progestin-mediated weakening of the lower esophageal sphincter as well as the mechanical effect of the gravid uterus. The American Society of Anesthesiologists' guideline recommends that pregnant patients undergoing elective surgical operation should not have any clear liquids 2 hours before surgery and no solid food should have been consumed 6 hours to 8 hours before surgery (40).

There is a remarkable increase in the risks associated with preterm labor in the perioperative period (41). If preterm birth is envisaged or considered high risk and the fetus is deemed potentially viable, prophylaxis with glucocorticoids should be considered. Physically, curtailing uterine manipulation may lessen the risk of uterus contraction and subsequent preterm labor (41, 42).

Due to the pregnancy-induced hypercoagulable state, depending on the location of the surgery, lower leg antiembolism stockings and sequential compression device leggings should be applied before induction of anesthesia (43).

Tetanus vaccination poses no risk to the pregnant mother or fetus (44). A fully immunized patient who has not received a booster within 5 years should receive 0.5mL of the tetanus toxoid injected intramuscularly. A patient who has not previously received a full course should receive both the tetanus toxoid and passive immunization (1, 44).

1.11. Intraoperative considerations

Subordinate to the probable hemodynamic repercussions of vena cava compression from an enlarged uterus, it is recommended that pregnant patients be positioned in the left lateral decubitus when possible (42). In the case of a left posterior wall acetabulum fracture typically approached from a right lateral decubitus position, prone positioning of the patient is also an acceptable alternative with ample padding of the abdomen to protect the gravid uterus (45). Some fractures cannot be managed with the patient in the full left lateral decubitus position. If the patient has an unstable spine

injury or a contraindication to this position, a wedge can be placed under the right side to tilt the spine and displace the uterus laterally (1, 46).

Based on the American College of Obstetricians and Gynecologists' release, the decision to use intermittent or continuous intraoperative fetal monitoring should be based on the type of surgery, available resources, and gestational age (47). In the first and early second trimester, fetal pulses are typically monitored before and after anesthesia exposure and operative intervention, but not during the operation. In the late second and third trimesters, secondary to the viability of the fetus, continuous intraoperative fetal monitoring via transabdominal ultrasonography is generally used. If the surgical field involves the abdomen, transvaginal ultrasonography can be used (42).

Intraoperative electronic fetal monitoring may be advisable if the conditions below are satisfied (43):

• The fetus is alive.
• It is physically probable
• A health care provider with obstetric privileges is available
• The physician obtained informed consent to perform an emergency cesarean delivery.
• The type of surgery will allow for safe disruption of the surgery for physicians to carry out an emergency delivery

One of the major concerns among patients and physicians when faced with the possibility of surgery during gestation, is what effect the anesthetic and adjuvant drugs will have on the developing fetus. None of the anesthetic agents has yet been acknowledged as a specific teratogen for humans, and anesthesia increases the risk of fetal hypoxia and preterm labor. Although the evidence currently remains encouraging, it is most sensible to defer elective surgery, until postpartum. If this is not possible then the first trimester should be avoided (48, 49).

The choice of anesthesia depends on maternal indications, the surgical location, and the method of surgery applied (50). Although general anesthesia is considered safe for use during pregnancy, the use of regional or if possible, local anesthesia may minimize fetal drug exposure (1, 50).

1.12. Fracture management

The prime objective in fracture fixation should be to apply the fixation procedure that entails the lowest possible radiation without endangering fracture care (51). Minimally invasive percutaneous plating techniques and intramedullary nails are commonly used in orthopedic surgeries. However, these difficult techniques often require high cumulative radiation exposures. When exposure to radiation poses a high risk, open plating techniques that involve minimal irradiation should be considered (51). Closed extremity fractures may be managed non-operatively, or treatment can be delayed until postpartum when appropriate (5).

Table 2: Estimated fetal radiation dose from conventional radiographic and computed tomography examinations

Examination	Dose (mGy)*
Radiography	
Cervical spine (AP, lateral)	<0.001
Extremities	<0.001
Chest (PA, lateral)	0.002
Thoracic spine	0.003
Abdomen (AP) (21-cm patient thickness)	1
Abdomen (AP) (33-cm patient thickness)	3
Lumbar spine (AP, lateral)	1
Computed tomography (CT) scan	
Head	0
Chest (routine)	0.2
Chest (pulmonary embolism protocol)	0.2
Abdomen	4
Abdomen and pelvis	25
CT angiography of the aorta	34
CT angiography of the coronary arteries	0.1

*: Estimated fetal dose. AP: anterior posterior; PA: posterior anterior

Acute pelvic or acetabular injury during pregnancy can put both mother and fetus at increased risk of mortality (36). If a symphyseal rupture is diagnosed clinically or radiographically and the patient is hemodynamically unstable, the most important intervention is the control of internal pelvic hemorrhage with provisional closed reduction of the pelvic ring. If closed pelvic fusion and resuscitation of fluid do not reestablish hemodynamic stability, venous plexus bleeding can be repaired through an open laparotomy with retroperitoneal packing and external fixation. If the hemorrhage source is from the arteries, it may be more favorable to perform angiography (1, 36).

Otherwise, management includes bed rest, traction, and a pelvic sling in most patients and early mobilization with a walker should be attempted. Surgical intervention on fractured pelvis is recommended when the patient suffers from an open tear in the pubic symphysis auxiliary to critical vaginal rupture, there is diastasis of the symphysis >4 cm, substantial malreduction of the pelvis, diastasis with the pelvic binder in place, or displacement of one or both sacroiliac joints. When prescribed, either peripheral fixation or open reduction and interior fixation should be performed within 3 weeks of injury. Peripheral fixation decreases further damage to the uterine environment and permits the fetus to reach 34 weeks' gestation. A supra-acetabular fixation approach can allow the patient to sit up and receive proper nursing care (1, 5).

The superiority of operative fracture management for fractures involving the acetabulum has been well covered, and it is well known that excellent results are lessened in the revision or salvage surgery or when operative care is delayed

for greater than 3 weeks. With the current evidence suggesting that fracture fixation, fluoroscopy, and general anesthesia may be safely delivered to the pregnant patient, open reduction and internal fixation of the acetabulum fracture may be the treatment of choice (52).

The occurrence of a pelvic fracture is not an outright indicator for avoiding vaginal delivery. If the pelvic architecture is not substantially disrupted, then a vaginal delivery can be safely performed (53). Normal healing takes 8 to 12 weeks after an injury. Thus, if the fracture happened during the early phases of pregnancy, vaginal delivery may be an option. If a pelvic fracture has healed without substantial residual pelvic malunion, and implants are appropriately placed within the bony pelvis, vaginal delivery should be attempted after evaluating the risk-benefit ratio for both the fetus and mother (1, 51).

1.13. Prevention and outcomes

Pregnant trauma patients have a two-fold risk of dying after the trauma as compared to their non-pregnant counterparts. Violent trauma rates tend to increase twice as much due to pregnancy, and mortality rate due to violent trauma is more than 3-fold higher compared to non-violent trauma (11).

Indelicate maternal trauma accounts for less than 1% of direct fetal injuries. The fetus is cushioned by the shock-absorbing effect provided by the amniotic fluid, uterus, and maternal soft tissues. A majority of fetal injuries happen during the late third trimester of pregnancy, which is characterized by shrinking of the uterine wall and thinned amniotic fluid. Placental break-off is a paramount impediment of maternal trauma, existing in 5-50% of manifestations. It is the most common cause of fetal death in cases of blunt trauma. The occurrence of abruption in significant blunt trauma results in fetal death 60% of the time, second only to maternal death (15, 53).

Although trauma is often unpreventable, there is significant documentation that seat belt utilization during pregnancy safeguards the mother and fetus (54). As reported by many investigations, the neglect of a seat belt or other restraints increases the risk of both maternal and fetal morbidity and mortality. Pregnant women who neglected the use of a seat belt during an automobile accident were 1.3-fold more likely to deliver an infant with low birth weight, had twice the possibility of experiencing disproportionate maternal hemorrhage, and were 2.8 times more certain to encounter a fetal death than women who put on a seat belt during an accident (55). In another study of pregnant patients involved in motor vehicle accidents, severe crashes in which the pregnant woman was not wearing a seat belt resulted in adverse outcomes 100% of the time (28). Seatbelt placement is also an issue, with nearly 50% of fetal losses associated with improper strap placement (30).

In some studies, airbag deployment during automobile accidents has been linked with fatal consequences such as uterine rupture, placental abruption, and fetal death. However, this probably reflects the magnitude of the force of the injury instead of being the cause. At this point, there are not enough data to make a recommendation about disabling airbags during pregnancy (15).

2. Conclusion

Overall, pregnant women with orthopedic injuries that are severe or even seemingly less severe, experience a significant increase in adverse pregnancy outcomes comprising preterm birth, placental abruption, poor infant condition at birth, infant death, and even maternal death. Many non-emergent pregnant orthopedic trauma patients can be managed conservatively, and delaying surgical treatment until after delivery is often a safe option. Notwithstanding, when medical attention is prompted in certain cases, the orthopedic surgeon must consider the physiological changes that accompany pregnancy and the potential risks to the fetus. Surgical positioning, administering medication, and diagnostic imaging are crucial considerations to ensure the best outcomes for both mother and child.

3. Declarations

3.1. Acknowledgments

The authors kindly appreciate all staff members of Imam Hossein Hospital who helped us to collect the data and perform this study.

3.2. Authors' contributions

MJK, AS and SSKH did the Investigation, Validation, Writing - Original Draft. Methodology, Formal analysis, Writing - Review & Editing. MS and AM: Project administration, Resources, Methodology. FB Methodology, Formal analysis, Writing - Review & Editing; AE: Conceptualization, Resources.

3.3. Funding and supports

This study did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

3.4. Conflict of interest

The authors affirm that they do not hold any conflict of interest either in financial terms or otherwise.

3.5. Ethical Considerations

All ethical principles were considered in this article.

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