Italian Journal of
Gynæcology & Obstetrics
June 2021 - Vol. 33 - N. 2 - Quarterly - ISSN 2385 - 0868

Post-partum hemorrhage: can it be prevented by assisting the natural physiological process?

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ABSTRACT

Background. Anteversion of the uterus is essential for the abdominal pregnant uterus growth and for the uterine contraction during labor and post-partum period. The role of the round ligaments is not yet completely understood, but certainly do have a coherent synergistic role with that of the neo-myometrium. The uterine contraction depends not only by the uterine muscle fibers, but also by the integrated pelvic myofascial system, connecting the uterine body to the round ligaments, to the ileo-psoas muscles and to the abdominal wall. In view of these functional anatomy reflections, it is possible to understand the procedures used in our management of postpartum hemorrhage and in our study.
Materials and methods. We have a retrospective observational study of a population of 5927 women who delivered by Cesarean Section or vaginal labor between 2014 and 2018, after the 34th gestational week. Of these, 173 women with risk factors for postpartum hemorrhage (PPH) or with mild PPH were treated with a non-invasive method consisting of an abdominal band for uterine compression/anteversion, in combination with standard drug or surgical therapy.
Results. We had only one peripartum hysterectomy on 5927 birth 0.016/1000 (Italy-ItOSS 1.08/1000, Regno Unit UKOSS-NethOSS-Nord Europa NOSS 0.3-0.4/1000). Five women received 4 or more blood transfusions on 5927 delivers (0.85/1000).
Conclusions. The non-invasive uterine compression technique reduced the incidence of PPH in high-risk women and prevented maternal morbidity and mortality.

SOMMARIO

Background. L'antiversione uterina è essenziale per l'espansione dell'utero gravidico nell'addome e per le contrazioni durante il travaglio e nel post-partum. Il ruolo dei legamenti rotondi non è ancora del tutto compreso, ma sicuramente ha un ruolo coerente e sinergico con quello del neo-miometrio. La contrazione uterina dipende non solo dalle fibre muscolari uterine, ma dal sistema integrato miofasciale pelvico, che collega il corpo uterino ai legamenti rotondi, ai muscoli ileo-psoas e ai muscoli della parete addominale. In considerazione di queste riflessioni anatomico-funzionali, è possibile comprendere le procedure che abbiamo utilizzato nella gestione dell'emorragia postpartum e nel nostro studio.
Materiali e metodi. Si tratta di uno studio retrospettivo osservazionale su una popolazione di 5927 donne che hanno partorito con taglio cesareo o per via vaginale in un periodo compreso tra il 2014 e il 2018, dopo la 34esima settimana gestazionale. Di queste, 173 donne con fattori di rischio per emorragia postpartum (EPP) o con lieve EPP sono state trattate con un metodo non invasivo costituito da una fascia addominale per la compressione/antiversione uterina, in combinazione con farmaci standard o terapia chirurgica.
Risultati. Abbiamo avuto solo un'isterectomia peripartum su 5927 nascite. 0.016/1000 (Italia-ItOSS 1,08/1000, Unità Regno UKOSS-NethOSS-Nord Europa NOSS 0,3-0,4/1000). Cinque donne hanno ricevuto 4 o più trasfusioni di sangue su 5927 parti (0,85/1000).
Conclusioni. La tecnica di compressione uterina non invasiva ha ridotto l'incidenza dell'EPP nelle donne ad alto rischio e ha evitato morbilità e mortalità materna.

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DOI: 10.36129/jog.33.02.05

Key words
Postpartum hemorrhage; cesarean section; operative delivery; device; uterine position; myofascial system; round ligaments.

INTRODUCTION

Did bipedal posture change only the pelvis?

The literature is rich of data on the pelvic changes related to human upright posture. The biological compromise was imposed on humans by two opposing biological pressures developing standing posture during our evolutionary process. It was called, in 1960, "obstetric dilemma" by the American bio-anthropologist Sherwood L. Washburn.
From an anthropological point of view, the reduction in the size of the birth canal in the human pelvis followed the adoption of bipedal posture. In addition, in nature there has been growth of large fetal skulls, in parallel to the growth of the neocortex volume. Anthropology and comparative anatomy show a bias linked to greater attention to the hard parts of the organism, which have been better preserved than soft tissues. Little attention has been taken, instead, with other important biological modifications imposed by the standing posture. The uterus arises in the most evolved primates from fusion of two horns, as present in the majority of the mammals. In fact, the Muellerian ducts are fused to give rise to bi-corneal uterus. In the more primitive mammals, however, there are two separate uteri and a double uterus occurs in the Marsupials, in many Rodent species and in bats (1).
Uterine malformations (septate uterus, uterus didelphis, *etc*.) derive from the same embryological origin. The presence of a single-space uterus has often been linked to the developmental needs of a single fetus, an advantageous way of having a single pregnancy from an evolutionary point of view. This observation is not consistent with many comparative anatomical studies. The mare, for example, which is a uniparous quadruped animal with a modified bipartite uterus, has an incidence of twin pregnancies between 1% and 16% and a very high number of poor outcomes (2).

Changing the position from quadruped to biped, on the contrary, required biological modifications also of the pelvic viscera. The erect position required postural uterine modifications which is very mobile, being able to assume all positions. Uterine orientation is conditioned by the women position, by the filling degree of bladder, rectum and intestinal loops, in harmonic physiological conditions (3). The wide uterine mobility is linked to the uterine muscle characteristics. Uterus is a unitary smooth muscle, like the bladder, differing from the multiunit smooth muscle, because the contractions are synchronized by communicating junctions, allowing to coordinate the cells contraction (4). The smooth muscle, despite having a myosin content of about 20% and a consumption of ATP 100 times lower than the skeletal muscle, can develop the same strength for transverse section area. It happens either for much slower rhythmical contractions, or for an architecture of the smooth muscle cell and the unitary organization of smooth muscle, structured in a syncytium (4, 5). A uterine muscle behaves like a viscous mass and it is also characterized by a tension variability exerted at any given extent, and there is either no relationship between extent and tension, nor between extent and a length of rest (6). Thanks to this plasticity, a strip of visceral smooth muscle, when stretched, first exerts a certain tension, but if the stretch is maintained, the tension gradually decreases and can go down to the initial or even lower level of tension (7).
The uterine tone is a persistent state of partial contraction, showing continuous irregular contractions independent from the innervation and the membrane potential is unstable, with no real resting value. A uterine muscle can, therefore, be considered as a "viscous mass" that needs to be oriented in extension and during contraction, with the lasting crucial role of the neo-myometrium and of the round ligaments (7). At the time of the fusion of the Muellerian ducts, the neo-myometrium,

peripheral layer of the uterus appears and develops mostly for functional reasons (8). It is known that the physiological uterine posture is usually in anteversion and this posture becomes necessary, for the purpose of maintenance of the species, especially at the end of the first trimester, to allow the uterus to develop outside the pelvis, avoiding rare cases of "uterine incarceration".
The need arises to anteriorize the uterus for its abdominal development during pregnancy which would otherwise be suffocated in the pelvis or could crush the large vessels, to place the cervix in the posterior fornix during coitus, but also because a uterus lying backwards after delivery does not contract well (6, 7, 9,10).

Round Ligaments these strangers: are they useful in pregnant physiology?

The role of round ligaments is poorly understood. They were credited for pulling the uterus forward during coitus, thus facilitating the entry of the semen into the cervical canal (11). Based on these assumptions, many uterine suspension surgeries during years 1950-1960 were performed. The role of round ligaments as a support structure for the non-pregnant uterus has become less convincing in recent decades. Nevertheless, the round ligament role in pregnancy and its function in labor tend to remain unchanged in obstetric textbooks (12).
From a phylogenetic point of view, it is in women that the round ligament reaches its greatest development and it is not an ancient vestige (13). The development of the round ligaments and the neo-myometrium is associated with the erect posture and the new reproductive needs and strategies connected to them (8, 14).
The round ligaments are improperly anatomically linked to the pelvic suspension system, because they are real muscles, as they can bear a load of up to 600 to 900 grams. Moreover, the round ligaments are the essential element that determines the orientation of the body of the uterus "like a horse held by the reins" (15). During pregnancy, the round ligaments become 3 to 4 times thicker and the resistance they offer to traction increases up to 40 kg. Always during pregnancy, is more anatomically evident (15) that they move away from the uterine fundus and the "Calza's Bundle" (central longitudinal band that in primates constitutes the neo-myometrium of the uterus, not more bicorned as in the quadrupeds) where they depart. It is probably due to the horn asymmetrical development, where the implant took place (7).
The round ligaments are formed by fibers and smooth muscle and, after the passage in the inguinal canals, by striated muscles from the transversus and oblique abdominal muscles, in analogy to the cremasteric muscles.
The round ligaments connect *fundus* of the uterus to *labia majora* and to the mons pubis and, even in sexual activity the stimulation of these areas leads to the uterine contractions of the orgasm (16). They are also present in quadrupeds, although they are poorly represented, since they obviously have a belly down and gravity favors the anterior position of the uterus. This biological finding shows that round ligaments have more a role of muscle nerve terminal than support (13) for connecting the external *genitalia* and the uterine horns (17).
Round ligaments orient uterine contraction also in labor, where there are different types of uterine contraction (18) with different receptors (or different sensitivity) for each muscular layer (neo-myometrium, paleo-myometrium and arch-myometrium) (6, 7, 9).
The Braxton Hicks contractions therefore serve to orient the uterus in the abdominal cavity during pregnancy and they also work in the latent phase of labor, to adapt the fetal head to birth canal. They are postural contractions related to round ligaments and the neo-myometrium, they cannot be the same muscle fibers that contract in the active phase of labor (19, 20).
The round ligaments and the neo-myometrial complex could orient the uterus, adapting to its content and playing an important role during pregnancy and labor (10).
The asymmetric position of the pregnant uterus at term, with a frequent dextro-position, is linked to the unequal contraction of the two round ligaments. The so called "ligament round pain", poorly diagnosed in Italy, is better known and investigated by Osteopaths, than by the Obstetrician.
Therefore, the evolutionary meaning of the neo-myometrium and the "new" round ligaments is not only to unify the two horns, but also to become the helm of the uterus (8, 11).
The gestational sac is usually located eccentrically in the uterine cavity because implantation occurs in one of the two horns even in a simple uterus (21, 22). Physiologically it cannot implant in the central part of the uterine cavity at the level of the neo-myometrium. The ultrasound report of gesta-

tional chamber in the center of uterine cavity might indicate an ectopic pregnancy (23).
Moreover, the numerous morphological variants of the placenta often have little clinical relevance, but they tell us the history of the migration of the trophoblast and the endometrial receptivity for embryo implantation (24). They are not physiologically possible in all areas of the uterine cavity, because the small contractions, useful for uterine posture, of the round ligaments and the neo-myometrium, in pregnancy would reduce the placental blood flow.
Mahran and Ghaleb (1964) have reported that strips of the human round ligament in its muscular portion contract spontaneously both in the non-pregnant and pregnant state and that they respond to electrical stimulation. They observed that during pregnancy spontaneous contractions of these strips were of low frequency and high tension, while during labor the contractions increased both in frequency and in amplitude and start asymmetrically from one of the two horns.
Synthetic oxytocin stimulates indistinctly and irregularly uterine contractions, but not always the round ligaments or, at least, not at the same time. Hence, synthetic oxytocin cannot help the uterine position (10, 19).
Today it is known that there is also a local (uterine) production of oxytocin demonstrated by the presence of oxytocin mRNA, at least in rats, and this could mean that for postural contractions (Braxton Hicks?) pituitary oxytocin is not needed. Furthermore, in the last expulsive phase of labor, during the disengagement of the fetal ("coronal") head, this presses, during vaginal distension, on the labia majora (also these more developed in women) (25) and on the terminal fibers of the ligaments rounds that contract and position the uterus contracted anteriorly (detrusorial contraction). The innervation of the so-called Geigel reflex, a less studied female count part of cremasteric reflex, is provided by the sensory and motor fibers of genital-femoral nerve originating from the L1-L2 spinal nerve nuclei, and whose genital branch reaches the inguinal canal and the round ligaments.

The hypothesis of integrated pelvic myofascial system and the "Tension network"

At the end of the first trimester, anteversion of the uterus, necessary for the abdominal expansion of the pregnancy, coincides with the accentuation of the lumbar lordosis, which is the spine adjusting to realign the center of gravity, in a non-casual harmony. It is linked to the relaxation of the ileo-psoas muscle, which is the main protagonist in determining the position of the pelvis and lumbar tract and consequently of the whole posture (26).
So far, most studies have been done on cadavers and the uterus and its ligaments have been studied sectorally *in vitro*. Today, by new imaging and radiological techniques and by the contribution offered by sports medicine, osteopathy and psycho-neuro-endocrine-immunology, it is possible to frame uterine contraction in a more global and more complex process (27).
The uterine contraction, in the expulsion phase of labor is "detrusor type", like the bladder, and the volume of the uterus decreases as its cavity is emptied. The uterine muscle, being in three layers, has the neo-myometrium (on the fundus) that continues with the fibers of the round ligaments (like a Bolivian wool cap). But this is still a partial view of complex pelvic supporting visceral system (28).
Uterine muscle is a complex system working by contraction, myofascial system and round ligaments, which constitute the link between the uterine muscle and the myofascial system.
Hence the hypothesis that the uterine contraction could depend not only by uterine muscle fibers, but by a complex integrated pelvic myofascial system, connecting the uterine muscle to the round ligaments, to the Ileo-Psoas muscles (via the genital femoral nerve) and to the muscles of the anterior and posterior abdominal wall.
The "axial fascia" or "deep fascia" (29) wraps and connects the uterine muscle, its ligaments, the postural muscles in a single interconnected system, that, after delivery, progressively returns to the "*status quo ante*". The term "fascia" refers to the collagen-fibrous tissues that are part of a broad system of transmission of tension forces in the human body (30-31). The "fascia" appears as an interconnected "tension network" consisting of the dense and loose connective tissue, from the surface to the depth. The ligaments are local densifications of this network. There is an extended continuity of the fibrous tissue, and the collagen tissue expresses a gradual transition. So, it is impossible to make a clear distinction between the ligament and the loose part of the intra-abdominal and pelvic fascia (32, 34).
Therefore, within the human body, the fascial body represents a wide anatomical structure with structural and functional network functions, consisting

of bags, ropes (local densifications), thousands of cavities inside other cavities, all connected by robust or soft septa (30, 33, 34).
The "visceral fascia" consists of collagen and elastic fibers and covers the body cavities (35). The bands wrapping the organs are called pleura, peritoneum, sheath, but they remain visceral bands (30-32, 34).
Currently, rethinking to obstetric daily experience in delivery room, it must, therefore, consider a re-arrangement of the whole myofascial system, favoring directly the abdominal viscera descent behind the uterus during labor and indirectly the in intra-abdominal pressure increase. In the human body architecture, the myofascial system is the anatomical structure which connects the anatomical districts and the human organs in the body (29).
In the postpartum uterine contraction, the uterine body is "guided" by the round ligaments, which contracts down and forward (35), and the lower uterine segment (LUS) contracts towards the pubic symphysis.
All the studies on uterine contraction focused on the characteristics of the muscle fiber and on the electrical potential of the membrane, rather than on the uterine muscle, structured in a syncytium.
Very interesting is the significant increase in the risk of "*postpartum* hemorrhage" PPH in Ehlers Danlos syndrome, characterized by severe connective tissue disorders. In fact, pregnant women with Ehlers Danlos syndrome experienced *postpartum* hemorrhage (19% *vs* 7%) more often than the unaffected women (36).
In light of these reflections, it is now possible to frame the procedures used in our management of postpartum hemorrhage and in the observational study, of which we will discuss, experience from which research on this rational functional anatomy emerged. The simplification and the progression of procedures (from simplex to complex) is necessary in complex tasks and is a necessity of medicine which is a procedural knowledge.

MATERIALS AND METHODS

In the obstetric department of Canosa and subsequently in the obstetric department of Barletta, for over twenty years in the postpartum, we have used an external uterine compression technique in all conditions at high risk for PPH as an aid in medical and surgical therapy (also after Bakri Balloon where necessary) of PPH. The aim was to help uterine contraction, preventing the "ascent" of the uterus and replacing manual massage. The compression band was positioned around the waist, above the contracted uterus after massaging it. It was more or less tight depending on individual needs. In severe cases, it also tightened to compress blood vessels and reduce arterial flow.
The logic of our use of the compression band was to mimic the natural physiological process of post-partum hemorrhage which is mainly mechanical contraction which happens immediately after the delivery and continues throughout the uterine involution. The Balloon is certainly helpful and we used it in our delivery rooms but it works exactly against the physiological way of hemostasis.

The technique therefore:
1. prevents the distension of the puerperal uterus;
2. also pushes the intestinal mass behind the uterine body;
3. assisting the anterior position of the uterus by pushing the lower uterine segment towards the symphysis as in bimanual compression.

In the case of mild *postpartum* hemorrhage or in the case of select risk factors our management has been:
- the first step was to do a noninvasive uterine compression, after manual massage;
- the first- and second-line drug therapy;
- the alarm;
- the exclusion of lacerations and rupture of the uterus or retention of placental material;
- the use of the intrauterine Bakri balloon;

Figure 1. *During Caesarians it can be verified that the thrust of the exteriorized uterus actually directs the LUS against the pubic symphysis. With the limit of the abdominal wall that prevents a complete anteriorization (in the cesarean section the abdomen is open), the bandage produces this movement.*

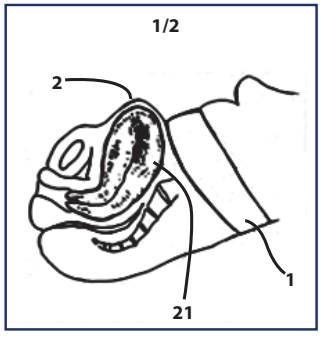

Figure 2.
1) position of application of the bandage, 2) external shape of the "safety globe", 21) contracted uterus.

- in case of postpartum hemorrhage during cesarean section or in case of placenta previa, the first step was the use of intrauterine balloon and then exertion of noninvasive uterine compression, after the closure of the abdominal wall, to obtain a double internal and external compression of the uterine muscle.

Application procedure

The application procedure includes the following steps:

1. manually and gently massage the uterus from the outside, in order to stimulate its contraction;
2. applying the bandage that compresses, in a circumferentially uniform manner, the abdominal area of the patient in at least a part of the region between the rib arch and the "safety globe", formed by the uterine contraction, leaving instead not compressed all the underlying abdominal region.

Safety globe is caused by the contraction of the uterine muscle and has the function of interrupting the bleeding resulting from childbirth. It is an easily identifiable anatomical part and, therefore, easily usable as a reference for the application of the fascia.

The area subject to compression is therefore entirely supra-umbilical, and as already explained it does not include the abdominal part under the navel which, indeed, must necessarily be left un-compressed for the execution of the method.

RESULTS

In the period between 2014 and 2018 we recorded 5927 deliveries. The rate of primary cesarean section (CS) in nullipara singleton vertex term (NSVT) pregnants ranged between 14 and 24%. This range is an indicator of the physiology propensity of the Operative Unit.

173 women, with risk factors or with initial hemorrhage from atony of the postpartum, have been treated with a non-invasive uterine compression technique. The orthopedic bandage for compressive wrapping was used. Nine pregnants with placenta previa or with bleeding due to suspected placental accretism, were treated with the simultaneous use of bandage and an intrauterine Balloon, to perform a double compression, internal and external.

Only one postpartum Hysterectomy among 5927 birth was necessary (0.016/1000) and only five women received 4 or more transfusions of blood on 5927 parts (0.85/1000).

All data are showed in **table I.**

DISCUSSION

Revising our results, the incidence of peripartum hysterectomies was significantly lower than in Italy (ItOSS 1.09/1000) and in Europe (UKOSS-NethOSS-Northern Europe NOSS 0.3-0.4/1000). The incidence of severe PPH was also lower than in Italy (1.12/1000) and in European average (0.3-1.2/1000) (37, 38). It is a retrospective observational study which could give an explanation and an anatomical functional rationale to an ancient method of uterine compression, the origins of which, with different tools such as bandages or belts, are lost in the mist of time and which today, in the light of new knowledge, can find a new dignity. Other trials are needed (39, 40). The purpose of this study is to demonstrate the need to learn the functional anatomy to respect physiology and help it with too hastily abandoned methods, which can be effective in light of current knowledge. There is a "global range" that, during pregnancy, is subject to mechanical tensions gradually increasing both from the growing fetus and from the pressures of the uterus (41). The abdominal diaphragm has a sort of dome turned upside down, the pelvic diaphragm is a dome upwards and these two muscle groups are located at the upper and lower extremities of the peritoneal cavity which, like a balloon, encloses the abdominal organs (42). The transmission of pressure takes place inside (intra-abdominal) and outside (abdominal and trunk muscles) of this balloon and it is transmitted to all the abdominal organs, by an integrated pelvic myofascial system (43). The contraction of the uterus in its natural position and of the round ligaments occur in this fundamental context (44).

The non-invasive uterine compression technique, used by us, helps the natural physiological processes that are sometimes altered, especially in the obese, in caesarean sections and in patients with obstetric complications like polyhydramnios and fetal macrosomia (45). The rationale integrates that of the old bimanual compression with the new role of the myofascial system.

Table I. *NSVT (Nulliparous, singleton, vertex, term) is used as an indicator of physiological management; 153 applications of tensoplast (abdominal bandage) prophylactic or therapeutic; all 9 cases of placenta previa treated with balloon and and tensoplast abdominal bandage; 1 Peripartum Hysterectomy/5927 birth (0.016/1000); 5 cases of severe bleeding treated with 4 or > pockets of red blood cells.*

YEAR	2014	2015	2016	2017	2018	Total
N° Births	1184	1203	1248	1196	1096	5927
Caesarean rate NSVT	20.60%	24%	13.80%	17%	23%	
n. compressions	26	33	40	39	35	173
Atony with haemorrhage	16	13	18	17	13	77
MODE OF DELIVERY						
Caesarean section	12	11	16	13	17	69
Vaginal birth	17	13	21	18	16	85
VBAC			1			
Induction of birth	2	3	7	3	4	19
Risk Factors						
Placenta praevia	0	0	1	3	5	9
Twin pregnancy	2	11	11	11	6	41
Manual placenta removal	3	1	1	0	0	5
Previous caesarean section	1	1	3	3	3	11
Primigravida	15	8	11	11	5	50
Parous	5	6	13	11	10	45
Preeclampsia	2	2	4	2	2	12
THERAPY						
Prophylactic compression	6	13	15	17	9	60
Therapeutic compression	12	13	14	14	16	69
Blood transfusions < 4 bags	3	6	6	6	5	26
Blood transfusions ≥ 4 bags	4*	0	3	1	1	9
BAKRI BALLOON	1	1	2	1	4	9
Hysterectomy peripartum	1					1
Admission in Intensive Care	1	0	1	0	0	2
Vagistop	1	2	2	0	0	5
Puerpuerium complications						
Puerperal Genitals Hematomas			1			1
Uterine Cavity Revisions			3			3

* Less than four pockets of red blood cells with fresh frozen plasma.

CONCLUSIONS

Our experience using orthopedic bendage in PPH prevention has allowed us to simplify the procedure therapy of PPH, to reduce the risks and improve the results. We used the balloon exclusively during CS in the case of placenta previa and/or suspected placental accretism and in combination with the same non-invasive external compression technique. Basing on our experience, we could propose to use the bandage also in several PPH in association with the Balloon to diminish the need for surgical procedures such as compressive surgical sutures and peripartum hysterectomies. The bandage use could replace other surgical uterine compression techniques, with a technique similar to bimanual compression, but without its discomfort. The validity of the observational studies compared to a controlled trials is demonstrated by the weight of the clinical results, as already described by Sackett, "inventor" of the EBM which gives the clinical experience the same weight as the statistical evaluation. Evidence based medicine is not restricted to randomized trials and meta-analyses. It involves tracking down the best external evidence with which to answer our clinical questions, without which they become "statistical games". And if no randomized trial has been carried out for our patient's predicament, we must follow the trail to the next best external evidence and work from there (46).

In a randomized study aimed at evaluating the effectiveness of these compression maneuvers, the control group would be formed by women who would present postpartum hemorrhage without receiving the same type of risk-free assistance. This would entail posed a significant ethical problem. Anyway, this proposal is a project at an initial step and needs to be improved with a large prospective trial.

ACKNOWLEDGMENTS

Profs. Costantino Mangioni, Francesco Bottaccioli, Michele Grandolfo, Sergio Schonauer and Vito Trojano for the authoritative support and encouragement.

CONFLICT OF INTERESTS

At the moment the authors declare that they have no conflict of interests.

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