

Effect of folic acid in a modified experimental model of anorectal malformations adriamycin-induced in rats¹

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ABSTRACT

PURPOSE: To determine the effect of a single dose of adriamycin (ADR) to induce anorectal malformations (ARMs) and determine the effect of folic acid (FA) in this model.

METHODS: Ten female Wistar rats were divided randomly in two groups. **Group A** – ADR; **Group B** – FA+ADR. Dams from group B received daily, since two weeks before the pregnancy to the end of pregnancy, FA (50mg/kg) by gavage. Dams from both groups received ADR (6mg/kg) by intraperitoneal injection on gestational day (GD) 8. Their fetuses were harvested by cesarean section on GD21 and were examined looking for ARMs. The thickness of anal stratified squamous epithelium (ASSE) and intestinal epithelium (IE) were analyzed. $p \leq 0.05^*$.

RESULTS: 81 fetuses were harvested. The number of fetuses; number of ARMs; mean ($\Delta\%$) (\pm SD) were determined to be, respectively: ADR – 41[29;65%(\pm 37%)] *versus* FA+ADR – 40[04;16%(\pm 36%)] ($p=0.05$). ARMs were significantly lower in FA+ADR group than in ADR group ($p=0.05$). The thickness (μ m) of ASSE (\pm SD) and IE (\pm SD) were measured, respectively: ADR – [25.98(\pm 0.74) and 19.48(\pm 1.68)] *versus* FA+ADR – [24.74(\pm 0.91) and 24.80(\pm 0.81)] ($p<0.005$). The thickness of IE was significantly enlarged when FA was given ($p<0.005$).

CONCLUSIONS: Single dose of adriamycin on D8 was able to induce anorectal malformations. Folic acid reduces the number and enlarged the IE of ARMs ADR-induced.

Key words: Anal Canal. Anus, Imperforate. Doxorubicin. Folic Acid. Rats.

Introduction

Anorectal malformations (ARMs) represent a broad spectrum of congenital anomalies, including anorectal and urogenital sinus defects. The incidence rate is approximately 1 per 5000 live births¹, occurring most frequently in males. Usually, the spectrum of AMRs presents defects on the terminal hindgut, anus, pelvic floor muscle (PMF) and striated muscle complex (SMC), innervations of PMF and SMC, androgenital and spinal defects. Posterior sagittal anorectoplasty (PSARP) has been proposed as gold standard surgery². Despite various advances in this technique, poor postoperative anorectal functions still remain as major problem. Fecal incontinence, constipation and voiding dysfunction are observed.

ARMs pathogenesis and morphogenesis remains unclear. Different teratogenic drugs have been used to mimic ARMs in rats. Different models of ARMs Adriamycin-induced have been published³⁻⁵.

Adriamycin (ADR) experimental model is a well established model of foregut anomalies in rats. These models can simulate VACTER association, including ARMs³⁻⁵.

Good evidence from randomized trials suggests folic acid (FA) reduces the risk for neural tube defects (NTD). Maternal consumption of folic acid before pregnancy and during early pregnancy is associated with a reduced risk for some other birth defects. The rate of ARMs was greater among mothers who did not take folic acid than mothers who took folic acid before pregnancy. Daily maternal consumption of 400 µg of folic acid could reduce the risk for AMRs⁴.

The aim of this study was to determine the effect of a single dose of adriamycin to induce anorectal malformations (ARMs) and determine the effect of folic acid (FA) in this model.

Methods

Ethical approval was obtained from the Research Ethics Committees of the Universidade Federal de São Paulo prior to the study (Protocol n° 1859/11).

Ten female mature Wistar-EPM rats were provided from the Central Biotery, UNIFESP. Rats were divided randomly in two groups. **Group A** – ADR and **Group B** – FA+ADR. One dam from group A died during pregnancy.

Dams from group B received daily, since two weeks before pregnancy to the end of pregnancy, FA (50mg/kg) by gavage.

Rats received commercial feed and water *ad libitum*, under constant environmental conditions of temperature and humidity, with 12-hour day and night cycles using artificial light, automatically controlled. After one night of mating, dams who presented a vaginal smear with the presence of spermatozooids were considered to be potentially fertilized. This was considered to be day zero (GD0) of gestation. Dams were kept in individual cages.

On gestational day (GD) 8, dams from both groups received ADR (6mk/kg) by intraperitoneal injection.

On GD21, dams were anesthetized with 2% xylazine (60mg/kg) and 10% ketamine (10mg/kg) by intramuscular injection. Fetuses were harvested by cesarean section and were initially examined externally looking for AMRs. Dams were sacrificed by cervical dislocation. Following this, fetuses were underwent to exploratory laparotomy to characterize the type of ARMs. Terminal intestine was removed to histological analysis.

Fragments of terminal intestine were fixed in 10% buffered formaldehyde, dehydrated and embedded in paraffin, stained with hematoxylin and eosin, and examined microscopically. The thickness of anal stratified squamous epithelium (ASSE) and intestinal epithelium (IE) were analyzed.

Non-parametric tests were used when samples tested against normal distribution. Kruskal-Wallis test was used to compare different groups and Mann-Whitney test when comparing two groups. Parametric tests were used in the histological analysis. Thickness was compared using two way Analysis of Variance (ANOVA) and post hoc Turkey test. Significant differences were considered when p values ≤ 0.05 .

Results

Eighty one fetuses were harvested. There were 41 fetuses from group A (ADR) and 40 fetuses from group B (FA+ADR).

In the ADR group, the mean weight of dams on GD0 and GD21 was, respectively 221.25g and 263.75g. In the FA+ADR group, the mean weight of dams on GD0 and GD21 was, respectively 229.40g and 287.20g ($p > 0.05$). In the ADR group, the mean weight (g) of fetuses \pm standard deviation (SD) was 2.00 ± 0.49 . In the FA+ADR group, the mean weight of fetuses \pm SD was 4.94 ± 0.89 ($p = 0.01$).

Statistically significant differences were observed comparing ARMs in 2 groups (Table 1). Folic Acid reduces the number of ARMs ADR-induced ($p = 0.05$). Typical anorectal area, in rats, was evidenced in Figure 1. ARMs were highlighted in Figures 2 and 3.

TABLE 1 - Presence of ARMs.

Group	Fetus	ARM	Mean (Δ %)	SD (%)
ADR	41	29	65%	37%
AF + ADR	40	4	16%	36%



FIGURE 1 - No ARM – AF + ADR group.



FIGURA 2 - ARM ADR induced – ADR group.



FIGURA 3 - ARM ADR induced, limb and facial defects – ADR group.

Some others anomalies were observed. Limb and facial defects, coexisting or not with ARMs, were observed in both groups. There was no significant difference ($p > 0.05$).

The thickness of anal stratified squamous epithelium (ASSE) and intestinal epithelium (IE) were analyzed (Table 2; Figures 4 and 5). Statistic significant differences were not observed on thickness of ASSE ($p > 0.05$). However, the thickness of IE was significantly enlarged when FA was given ($p < 0.005$).

TABLE 2 - Thicknes of ASSE and IE.

Group	ASSE \pm SD (μ m)	IE \pm SD (μ m)	ARM (%)
ADR	25.98 \pm 0.74	19.48 \pm 1.68	65%
AF + ADR	24.74 \pm 0.91	24.80 \pm 0.81	16%

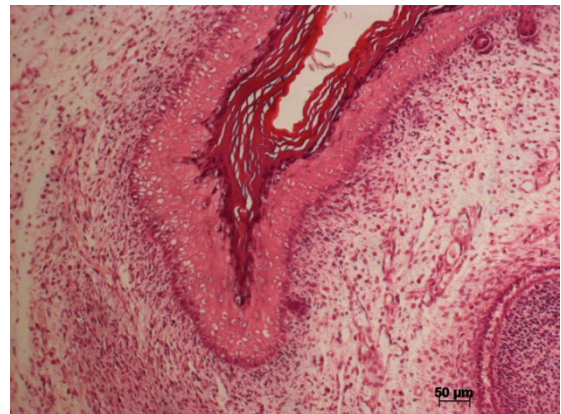


FIGURE 4 - Thickness of ASSE – ARM – ADR-group (x20).

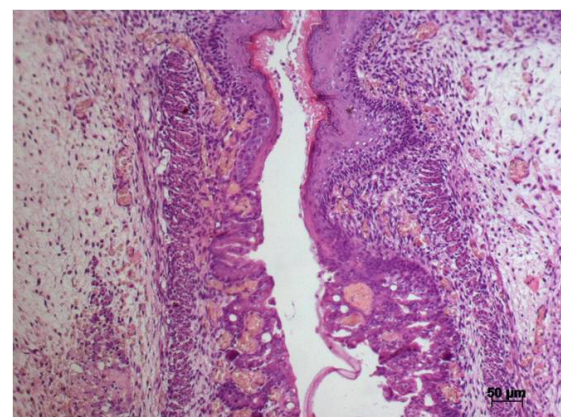


FIGURE 5 - Thickness of IE - No ARM - FA+ADR group (x 20).

Discussion

ARMs are among the most common congenital anomalies in humans. In male, rectourethral fistula has been the most usually

presentation linked to ARMs, while vestibular fistula has been the most usually presentation in females. The most of them present as an isolated malformation, although it may be part of VACTERL anomalies. The term VACTERL represents vertebral, anorectal, cardiovascular, tracheal, esophageal, renal and limb anomalies.

Currently, PSARP² has been performed throughout the world. This technique allowed better understanding of anorectal anatomy. Despite optimal surgical management, many patients reclaim of bowel and voiding dysfunction. These dysfunctions occur probably because no adequate repair for poorly developed muscles or nerves has been developed at this time.

ARMs pathogenesis and morphogenesis remains unclear. Various experimental models have been published using different animals. Rats are the most common animal used, including mutant mice. Different teratogenic drugs have induced ARMs in rats. Different models of foregut anomalies ADR-induced have been published³⁻⁵.

Initially, 2 mg/kg of ADR were given on GD 6 through nine to establish an esophageal atresia experimental model⁶. This model had been changed, using ADR on GD 7, 8 and 9 (7), or using higher doses on GD 7 and 8^{3,4}.

When using higher doses of ADR on GD 7 and 8, ARMs were induced in all fetuses. ARMs were associated with extensive bowel agenesis or with rectal atresia followed by blind-ended stratified squamous epithelium in some of those fetuses. Most of them had small or absent external genital tubercles and shortened tails³. From this moment, this model became a well established an ARMs ADR-induced experimental model in rats.

Some others experimental models replicate the findings of ADR experimental model. Mutant mice with various defects in the Sonic hedgehog (*Shh*) signaling pathway exhibit spectrum of distal hindgut defects mimicking human anorectal malformations. *Shh* null mice fail to develop an anus, rectum, and lower urinary tract, quite similar to ADR model⁸.

Abnormalities in the notochord were demonstrated in ADR model. A delayed separation of the notochord from the gut endoderm leads notochord to develop abnormal branches out toward the gut⁷. Notochord remained tethered to the foregut with an increased dorsoventral diameter⁹. Was suggested a causative link between abnormalities of the notochord and hindgut malformations⁵ and the notochord may have a critical importance in the development of ARMs⁹. *Shh* signaling pathway is essential for normal patterning of the foregut and hindgut. A close relationship between *Shh* expressing on notochord branches and on hindgut was reported⁵.

In this study, our group presents a different experimental model of ARMs ADR-induced. ARMs were induced using only one dose of ADR (6mg/kg) on GD 8. In this modified model, 65% of ARMs were induced by ADR, not even close to previous results using 2 or 3 doses of ADR³⁻⁵. Our results are similar to experimental model of ARMs ethylenethiourea induced¹⁰⁻¹³. The mean weight of the fetuses of dams who received ADR was less than the fetuses of dams who received FA + ADR. The low weight of fetuses was also described by others authors¹⁴.

Postoperative anorectal function depends on many factors, such as pelvic floor muscles, innervation of pelvic floor muscles, and no spinal cord anomalies. Striated muscle complex (SMC) is one of the most important factors related to anorectal function. Various defects in SMC were described in ARMs, such as the increased distance between SMC and the perineal skin¹⁵.

Internal anal sphincter (IAS) is very important to continence. IAS is responsible for the normal rectal anal inhibitory reflex controlling the resting tonus in the anal canal and keeping the anus closed. These muscles are dysplastic in rats with ARMs¹⁶.

In this study, the thickness of ASSE was thick in ADR group and the thickness of IE was thin in ADR group. Folic acid did not modify significantly the thickness of ASSE. On the other hand, the thickness of IE was significantly thicker in FA+ADR group than in ADR group. Fetuses with ARMs presented both thickness of ASSE and IE smaller than normal rats, but it was not possible to prove by statistical analysis. This analysis was only able to compare entire groups, but not each fetus individually.

Folic acid or folate is the generic term of a water soluble B vitamin. Folic acid has low toxicity. The term folate refers to the deprotonated ion, while folic acid refers to the neutral molecule or the synthetic form of vitamin B. Folic Acid is more stable than folate.

Maternal FA deficiency was correlated with neural tube defects (NTD).FA provides well-documented benefit for the prevention of NTD and craniofacial defects. Currently, many countries recommend that all women planning or capable of pregnancy take a daily supplement containing 400-800µg of folic acid¹⁷⁻¹⁹.

Few authors have studied the relationship between FA and ARMs, and their results are unclear. Some of them had not found any difference in development of ARMs when FA was taken²⁰⁻²². On the other hand, other authors had related some protection of FA in development of ARMs²³⁻²⁵.

During folate metabolism, folate is converted by dihydrofolate reductase (DHFR) to tetrahydrofolate (THF), the naturally bioactive form. Methylene tetrahydrofolate

reductase (MTHFR) catalyzes the conversion of THF to 5-methyltetrahydrofolate (5-MeTHF), the main form of folate in the blood circulation. Low enzyme activity of MTHFR reduces 5-MeTHF plasma levels, leading to increased levels of homocysteine. These changes have been related to neural tube defects. No relationship between ARMs and reduced enzyme activity of MTHFR was found²².

In this study, we were able to induce ARMs using a single dose of ADR. Nevertheless, the number of ARMs was lower when using a single injection than when using 2 or 3 injections. The effect of FA in this model is important to highlight, reducing significantly the incidence of ARMs from 65% to 16% ($p=0.05$). Further studies are necessary to explain how folic acid acts in this model.

Conclusion

Single dose of adriamycin on D8 was able to induce anorectal malformations. Folic acid reduces the number and enlarged the IE of ARMs ADR-induced.

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