Effects of a Thromboxane A_2 Analogue and Prostacyclin on Lung Fluid Balance in Newborn Lambs

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We have previously shown that the pulmonary venoconstriction produced by a stable thromboxane A_2 analogue (STA_2) is attenuated by prostacyclin (PGI_2), but PGI_2 increases the STA_2-induced edema. The present study was designed to determine the effects of STA_2 and PGI_2 on the fluid balance in isolated blood-perfused newborn lamb lungs. Vascular permeability was evaluated by use of the fluid filtration coefficient (Kf) and the osmotic reflection coefficient for total proteins (σ, hematocrit-protein double indicator technique), and pulmonary capillary pressure (Pc) was estimated by the double occlusion technique. All lungs had a period of hydrostatic stress induced by elevation of the left atrial pressure from 5 to 20 mm Hg to promote fluid filtration, and the rate of lung weight gain ($\Delta W/\Delta T$) during this period was determined. Studies were made in four groups; before the hydrostatic stress, lungs were given 1) STA_2 (50 μg, $n=6$), 2) PGI_2 (0.4 $\mu g/kg/min$, $n=6$), 3) both PGI_2 and STA_2 ($n=6$), or 4) vehicles (control, $n=5$). Measurements of Kf were made at the baseline period and after the hydrostatic stress. Kf was significantly increased by 76% with STA_2, by 121% with PGI_2, and by 157% with both PGI_2 and STA_2, but remained constant in controls. In comparison with control lungs, a similar $\Delta W/\Delta T$ was observed with less of an increase in Pc during the hydrostatic stress in the STA_2 group, and greater values of $\Delta W/\Delta T$ were obtained with smaller elevations in Pc in the groups receiving PGI_2 or both PGI_2 and STA_2. The σ of 0.66 ± 0.07 in the control group was the highest in these experiments. Treatments with STA_2 and/or PGI_2 significantly decreased σ. These results suggest that both STA_2 and PGI_2 may increase pulmonary microvascular permeability to protein. Furthermore, PGI_2 may increase fluid filtration by increasing vascular surface area. (*Circulation Research* 1989;65:1409–1416)

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Thromboxane A_2 (TxA_2) is a potent pulmonary vasoconstrictor that may be involved in the early phase of endotoxin-induced pulmonary hypertension and edema. This pulmonary hypertensive response has been suggested to be the result of TxA_2-mediated pulmonary venoconstriction since the protein-poor lung lymph flow is increased in this early phase.[1,2] By use of the arterial and venous occlusion technique in isolated newborn lamb lungs, we have recently demonstrated that a stable TxA_2 analogue, 9,11-epithio-11,12-methano-TxA_2 (STA_2), produced pulmonary hypertension primarily by causing pulmonary venoconstriction.[3] Although exogenous prostacyclin (PGI_2) attenuated this response to STA_2 by decreasing the pulmonary venoconstriction, PGI_2 administration significantly increased the STA_2-induced pulmonary edema.[3] These observations were interpreted as being consistent with an increase in microvascular permeability by PGI_2 that potentiated the STA_2-induced pulmonary edema, despite the attenuation of the elevation of the pulmonary microvascular pressure by PGI_2. However, the possibility that PGI_2 increased lung vascular surface area rather than permeability was not completely excluded in this study because vascular permeability was not directly evaluated.

Pulmonary microvascular membrane permeability may be estimated by changes in filtration coefficient (Kf) in isolated perfused lungs.[4] However, when changes in the number of perfused microvessels occur, as with microvascular embolism, vasodilation, or vasoconstriction, Kf may not be a reliable parameter of changes in permeability because Kf depends on membrane surface area.[5] In

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contrast, the osmotic reflection coefficient is a measure of membrane permeability to proteins that is independent of vascular surface area.[4] The purpose of this study was investigation of the effects of STA_2 and PGI_2 on transvascular fluid and protein exchange in isolated newborn lamb lungs by use of both the fluid filtration and the osmotic reflection coefficients as indicators of microvascular permeability change.

Materials and Methods

Isolated Lung Preparation

Our method of isolated lung preparation has been previously described.[3] Briefly, 23 newborn lambs of either sex, 0–4 days of age and weighing between 2.1 and 5.5 kg, were anesthetized with ketamine hydrochloride (50 mg/kg i.m.), and a catheter was placed in a femoral artery. After administration of heparin (3,000 units), the animals were exsanguinated through the catheter. A tracheotomy was performed and the pulmonary artery and left atrium were cannulated. The lungs were rapidly and carefully removed and weighed. After the lungs were placed on a weighing instrument suspended from a strain-gauge force transducer (model FT 10, Grass Instruments, Quincy, Massachusetts), the cannulas were connected to an extracorporeal perfusion system[3] consisting of a reservoir that could be adjusted to set outflow pressure at any level, a roller pump (Varistaltic S-series, Manostat, New York) for constant flow, a heat exchanger (Pediatric Miniprime, Baxter Healthcare, Deerfield, Illinois), a blood filter, an electromagnetic flow probe (model EP 300 A 1/4, Carolina Medical Electronics, King, North Carolina), and a manually actuated bypass valve that allowed for the rapid diversion of flow from the lungs directly back to the reservoir. The lungs were perfused with heparinized autologous and donor blood in a recirculating manner at a constant flow of 50 ml/kg body wt/min. For prevention of the endogenous release of products of the cyclooxygenase pathway of arachidonic acid metabolism, which may modulate responses to STA_2 and PGI_2, prostaglandin synthesis was inhibited by the addition of indomethacin (40 μg/ml) to the blood. The perfusate blood temperature was monitored by a thermistor in the perfusion circuit and maintained between 38° and 39° C with the heat exchanger. The blood O_2 and CO_2 tensions and pH were measured using a pH/blood gas analyzer (Corning Medical, Medfield, Massachusetts), and pH was maintained between 7.35 and 7.45 by addition of 1N $NaHCO_3$ to the reservoir, as necessary. The perfusate glucose concentration was measured using Dextrostix (Miles Laboratories, Elkhart, Indiana) and maintained above 90 mg/dl by addition of 50% glucose solution to the reservoir.

The lungs were covered with plastic wrap to prevent evaporative fluid loss and were ventilated with a warm, humidified gas mixture of 28% O_2, 5.4% CO_2, and 66.6% N_2 at a tidal volume of 15 ml/kg, a rate of 10–12 breaths/min, and an end-expiratory pressure of 3 mm Hg, and were periodically hyperinflated for prevention of atelectasis.

Mean pulmonary arterial (Ppa), mean left atrial (Pla), and tracheal pressures were measured with pressure transducers (Statham models P10EZ and P23ID; Spectramed, Oxnard, California). The zero reference for all transducers was the top of the lungs, and the outflow pressure was adjusted to 5 mm Hg so that all lungs remained in zone 3 conditions. The flow rate of the perfused blood was measured with an electromagnetic flowmeter (model FM 501D, Carolina Medical Electronics). Lung wet weight and the pressures were continuously recorded on a physiological recorder (model 7D, Grass Instruments).

Estimation of Pulmonary Capillary Pressure

Pulmonary capillary pressure (Pc) was estimated by the double occlusion technique, as previously described.[6–8] The respirator was turned off at end-expiration before occlusion. Arterial inflow and venous outflow occlusions were performed in duplicate by simultaneous diversion of inflow from the lungs to the reservoir by means of the bypass valve and clamping of the outflow tubing, respectively. The time courses of Ppa and Pla were monitored on an X-Y-Y recorder (model 50,000 S, Gould, Cleveland, Ohio). During the occlusion period, Ppa and Pla rapidly equilibrated to the same or nearly the same pressure. The Pc was taken as the equilibrium pressure at 5 seconds after occlusion. However, in the cases of vasoconstriction induced by STA_2, Ppa did not equilibrate with Pla after occlusion. Thus, in these conditions Pc was determined as the equilibrium pressure for Pla at 5 seconds after occlusion.[8]

Determination of Pulmonary Capillary Filtration Coefficient

The capillary Kf was measured as previously described.[9] After achievement of isogravimetric conditions, Pla was rapidly raised by 5–8 mm Hg by elevation of the reservoir for 7 minutes. The Pc was measured immediately before the increase in Pla and at the end of the 7-minute elevation of Pla to obtain the difference. The rapid lung weight increase during the first 2 minutes after Pla elevation corresponds to a vascular volume change, and the slower component represents transvascular fluid filtration.[9] The rate of lung weight increase was measured for each minute after elevation of Pla and was expressed as a semilogarithmic function over time. The slower component of weight increase was extrapolated to time 0 for estimation of the fluid filtration rate. This value was then divided by the change in Pc for calculation of Kf. The Kf was expressed in milliliters per minute per mm Hg per 100 g wet lung weight.

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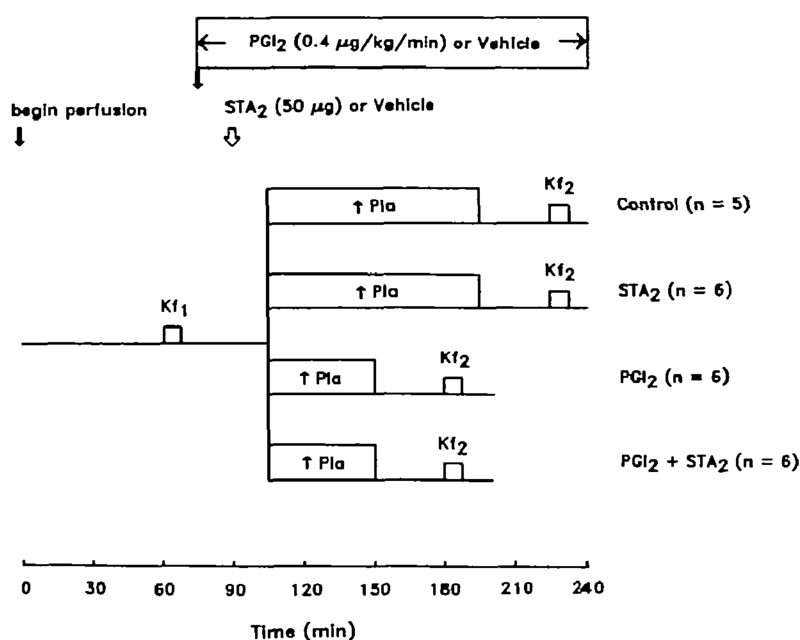

FIGURE 1. *Diagram of experimental protocol. In all experiments, hydrostatic stress was maintained for 90 minutes or until lungs had tripled in weight. PGI_2, prostacyclin; STA_2, thromboxane A_2 analogue; Kf_1, Kf_2, baseline and final fluid filtration coefficients, respectively;* ↑ *Pla, hydrostatic stress induced by elevation of left atrial pressure from 5 to 20 mm Hg.*

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Estimation of Osmotic Reflection Coefficient

For estimation of the osmotic reflection coefficient (σ), red blood cells and the plasma proteins were considered as endogenous nondiffusible and diffusible indicators, respectively.[10,11] The relative increases in hematocrit and plasma protein concentration resulting from movement of fluid from the vascular to the extravascular space can be calculated from the equation[12–14]

$$\sigma=1-C_2/C^*[1-(1-H_1)\ (1-C_1/C_2)/(1-H_1/H_2)]$$

where C_1, C_2, and C^* are the initial, final, and mean protein concentrations, respectively, and H_1 and H_2 are initial and final hematocrits. The osmotic reflection coefficient was corrected for the degree of hemolysis produced by the perfusion pump and the filtration fraction, as previously described.[12–14]

Hematocrit was determined in quadruplicate by the microhematocrit technique, and the plasma protein and blood or plasma hemoglobin concentrations were measured by spectrophotometer (model DU-70, Beckman Instruments, Fullerton, California) in duplicate by the protein-dye binding technique[15] (Bio-Rad Protein Assay Kit, Bio-Rad Laboratories, Richmond, California) and cyanmethemoglobin technique[16] (Hemoglobin Assay Kit No. 525, Sigma Chemical, St. Louis, Missouri), respectively.

Experimental Protocol

We evaluated the effects of STA_2 and PGI_2 on pulmonary microvascular permeability as measured by the capillary filtration coefficient and the osmotic reflection coefficient in four experimental groups (Figure 1):

1) Vehicle control group (n=5). During the initial 60 minutes of equilibration, the lungs were allowed to reach an initial isogravimetric state. Baseline filtration coefficient (Kf_1) was determined by elevation of the Pla. After the lungs achieved an isogravimetric state by the restoration of Pla to the baseline level, Pla was raised from 5 to 20 mm Hg by elevation of the height of the reservoir (hydrostatic stress). Under maintained hydrostatic stress, filtration was allowed to continue for 90 minutes or until the lung weight gain was approximately 200% of initial lung weight. Then Pla was decreased to the baseline level, and the lungs were allowed to reestablish a new isogravimetric state; the final filtration coefficient (Kf_2) was determined by elevation of Pla to a level similar to that used for Kf_1. These control lungs also received vehicles for both STA_2 and PGI_2.

2) STA_2 group (n=6). After the equilibration period and Kf_1 measurement, the lungs were given a bolus injection of STA_2 (50 μg) into the pulmonary arterial cannula. After the lung weight was stabilized, the hydrostatic stress was performed 15 minutes after the STA_2 injection and maintained as described above. Then Kf_2 was determined by elevation of Pla to a level similar to that used for Kf_1. This group also received the vehicle for PGI_2.

3) PGI_2 group (n=6). After the equilibration period and Kf_1 measurement, the lungs received a continuous infusion of PGI_2 (0.4 μg/kg/min) through the pulmonary arterial cannula by use of an infusion pump (model 935, Harvard Apparatus, South Natick, Massachusetts). The infusion was maintained for the duration of the experiment. After the lung weight was stabilized, the hydrostatic stress was performed and maintained as described above. Then Kf_2 was determined by elevation of Pla to a level similar to that used for Kf_1. This group also received the vehicle for STA_2.

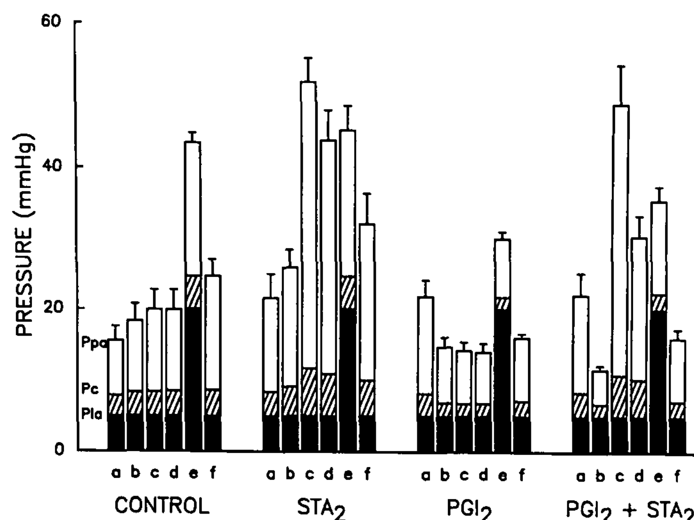

FIGURE 2. *Hemodynamic values of pulmonary arterial (Ppa), capillary (Pc), and left atrial (Pla) pressures in four groups. Standard error bars are given for Ppa. Measurements were made at the following time points: a, baseline; b, PGI_2 or vehicle; c, STA_2 or vehicle; d, 15 minutes after STA_2 or vehicle injection; e, hydrostatic stress by elevation of Pla; f, restoration of Pla to baseline level. STA_2, thromboxane A_2 analogue; PGI_2, prostacyclin.*

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4) PGI_2 and STA_2 group (n=6). After the equilibration period and Kf_1 measurement, the lungs received a continuous infusion of PGI_2. A bolus injection of STA_2 was administered 20 minutes after the beginning of the PGI_2 infusion. After the lung weight was stabilized, the hydrostatic stress was performed and maintained as described above. Then Kf_2 was determined by elevation of Pla to a level similar to that used for Kf_1.

Blood samples (4 ml) for measurements of hematocrit and plasma protein or hemoglobin were drawn every 30 minutes in all groups.

The effects of hemolysis, resulting from pumping blood through the perfusion system, on hematocrit and plasma protein concentrations were evaluated in four separate studies. Approximately 750 ml of heparinized blood was circulated in the same system used in the perfused lung study at a constant flow rate of 180 ml/min for 180 minutes. The blood volume and flow rate were chosen to approximate those of mean values in perfused lung experiments. Blood samples (4 ml) were drawn every 30 minutes for 180 minutes. The relationships between hematocrit and plasma hemoglobin concentration and between plasma protein and plasma hemoglobin concentrations were analyzed by linear regression analysis. The average slopes of the regression equations were used to correct the hematocrit and plasma protein concentration to a state of no hemolysis, as described by Maron et al.[12] In addition, the final plasma hemoglobin concentration was corrected for filtration-related loss of plasma in each experiment.[12]

A stock solution of STA_2 (100 μg, Ono Pharmaceutical, Osaka, Japan) was prepared by dissolving in 95% ethanol (1 ml) and diluting to 10 ml in 0.06 M monobasic-dibasic phosphate buffer (pH 8.0) and stored at −20° C. PGI_2 (Burroughs-Wellcome, Research Triangle Park, North Carolina) was dissolved in glycine buffer (pH 10.5) immediately before use.

At the end of the experiment, a final blood sample was taken, and the lungs were rapidly removed from the perfusion system. The lungs were then homogenized, and extravascular lung water was determined and expressed as the ratio of extravascular lung water to dry bloodfree lung, according to the method of Pearce and coworkers[17] and Selinger and associates.[18]

Statistics

The data are expressed as mean±SEM. Regression lines were obtained using least-squares linear regression. The changes induced by the treatments with STA_2 and PGI_2 within and between groups were evaluated by analysis of variance and least significant difference. Comparisons between these treatments and the control group were assessed using Dunnett's t statistic. Significance was determined when $p<0.05$ was obtained.[19]

Results

Hemodynamics

Figure 2 summarizes the hemodynamic data from the four groups. The original baseline values (a) of Ppa and Pc were similar in all groups. There were tendencies in the control group for Ppa and Pc to increase during (b and c) or after (d) the administration of vehicles, but these changes were not statistically significant. The hydrostatic stress resulting from the elevation of the Pla by 15 mm Hg (e) increased Ppa and Pc from 19.9±2.8 to 43.4±1.4 mm Hg and from 8.5±0.6 to 24.6±0.6 mm Hg, respectively. The restoration of the Pla to the baseline level (f) resulted in a return of Pc to a level similar to the baseline value, but Ppa remained elevated for the duration of the study.

Injection of STA_2 (50 μg bolus, at c) produced considerable increases in Ppa from 25.8±2.5 to 51.8±3.2 mm Hg, and in Pc from 9.1±0.2 to 11.7±0.4 mm Hg. Although these pressures gradually declined, they remained elevated at 15 minutes (d), before the hydrostatic stress was performed. Elevation of Pla by 15 mm Hg (e) produced an

TABLE 1. Effects of STA_2 and PGI_2 on Transvascular Fluid Filtration in Isolated Newborn Lamb Lungs

	n	Kf_1 (ml/min/mm Hg/100 g wet lung wt)	Kf_2 (ml/min/mm Hg/100 g wet lung wt)	σ	EVLW/BFDLW
Control	5	0.18±0.02	0.20±0.02	0.66±0.07	8.25±0.58
STA_2	6	0.17±0.01	0.30±0.02*†	0.31±0.02*	8.88±0.66
PGI_2	6	0.19±0.02	0.42±0.03*†‡	0.32±0.05*	8.43±0.98
PGI_2+STA_2	6	0.14±0.01	0.36±0.02*†‡§	0.40±0.05*	10.28±1.30

Data are mean±SEM. STA_2, thromboxane A_2 analogue; PGI_2, prostacyclin; *n*, number of experiments; Kf_1, Kf_2, baseline and final fluid filtration coefficients, respectively; σ, osmotic reflection coefficient; EVLW, extravascular lung water; BFDLW, bloodfree dry lung weight.

*$p<0.05$ vs. control.

†$p<0.05$ vs. Kf_1.

‡$p<0.05$ vs. STA_2.

§$p<0.05$ vs. PGI_2.

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increase in Pc of 13.3±0.8 mm Hg. This increase in Pc by the hydrostatic stress was significantly less than that in the control group (15.9±0.6 mm Hg). After restoration of Pla to the baseline level (f), both Ppa and Pc remained elevated for the duration of the experiment.

Infusion of PGI_2 (0.4 μg/kg/min, at b) significantly decreased the baseline values of Ppa and Pc. Elevation of Pla (e) increased Pc by 14.9±0.1 mm Hg which was not significantly different from that in the control group.

The peak pressor responses of Ppa and Pc to STA_2 (c) during PGI_2 infusion did not differ from those without PGI_2. Although Ppa was significantly lower at 15 minutes after the STA_2 injection (d) in the group receiving the PGI_2 infusion than in the group without PGI_2, the values for Pc were not significantly different. Elevation of Pla (e) produced an increase in Pc of 12.1±0.9 mm Hg, which was significantly less than the values in the control and PGI_2 groups, but was not different from the STA_2 group.

Fluid Filtration and Osmotic Reflection Coefficients

The fluid Kf and σ measured in the four groups are shown in Table 1. There were no differences in Kf_1 between groups. The Kf_2 in the control group did not differ from the original baseline value. However, Kf_2 was increased from baseline by 76% with STA_2, by 121% with PGI_2, and by 157% with both PGI_2 and STA_2. In addition, the value for Kf_2 in the group receiving both PGI_2 and STA_2 was significantly higher than that in the STA_2 group. Furthermore, the value for Kf_2 in the group receiving PGI_2 alone was significantly greater than that in the group receiving both PGI_2 and STA_2. Treatments with STA_2 and/or PGI_2 significantly decreased the reflection coefficients; however, there were no statistical differences among these three treatment groups.

Weight Gain by Left Atrial Pressure Elevation

Elevation of Pla produced a progressive gain in the lung weight with the pattern of increase exhibiting two components: 1) a rapid component attributed to vascular volume change (the first 2 minutes) and 2) a slower component representing fluid filtration (Figure 3). The slope of the line during the slower phase indicates the rate of lung weight gain (ΔW/ΔT) induced by the hydrostatic stress. In the group receiving STA_2, ΔW/ΔT did not differ from the control group. On the other hand, there were marked increases in ΔW/ΔT during the hydrostatic stress in the groups receiving PGI_2 (either with or

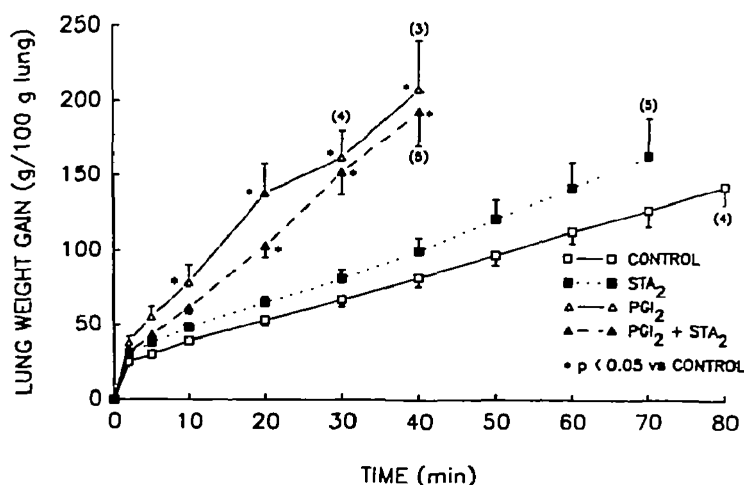

FIGURE 3. *Time course of lung weight gain during elevation of left atrial pressure.* n=5 *in control group and 6 in other three groups, except for numbers in parentheses. STA_2, thromboxane A_2 analogue; PGI_2, prostacyclin.*

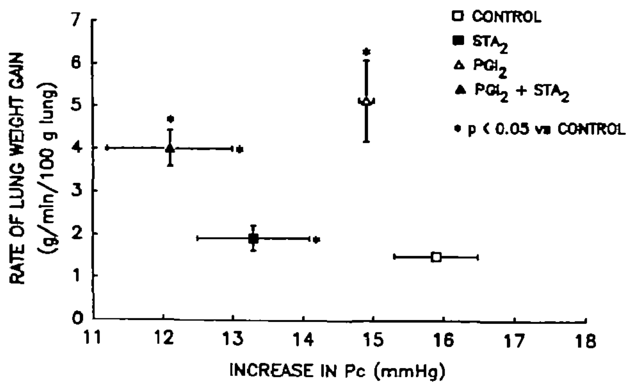

FIGURE 4. *Relationship between increase in pulmonary capillary pressure (Pc) and rate of lung weight gain induced by elevation of left atrial pressure. STA_2, thromboxane A_2 analogue; PGI_2, prostacyclin.*

without STA_2). Because of higher filtration rates, the hydrostatic stress was maintained for approximately 45 minutes (mean values) in the groups receiving PGI_2, as compared with 70–80 minutes in the other two groups. Restoration of Pla to the baseline level resulted in a rapid reduction of lung weight by an amount equal to the initial vascular volume increase seen with the Pla elevation, and the isogravimetric condition was reestablished (but at a higher level of lung weight) after 30 minutes. At the end of the experiment, the PGI_2-treated lungs (either with or without STA_2) had macroscopically apparent diffuse hemorrhagic edema.

The relationships between $\Delta W/\Delta T$ and the increase in Pc produced by elevation of Pla are shown in Figure 4. Compared with control lungs, the hydrostatic stress produced a similar $\Delta W/\Delta T$ with a smaller increase in Pc in the STA_2 group, but greater values of $\Delta W/\Delta T$ with smaller or comparable increases in Pc were observed in the groups receiving PGI_2 or both PGI_2 and STA_2. Lungs receiving both PGI_2 and STA_2 had a higher value of $\Delta W/\Delta T$ than in the STA_2 group, although a similar increase in Pc was observed.

The ratios of extravascular lung water to dry bloodfree lung obtained at the end of the experiment did not differ among the four groups (Table 1).

Discussion

In the present study, we observed increases in vascular permeability in neonatal lungs receiving either STA_2 and/or PGI_2 compared with control lungs, as indicated by increases in Kf and decreases in σ. Furthermore, Kf was significantly increased in both groups receiving PGI_2 as compared with the group receiving STA_2 alone, despite comparable values of σ. In addition, the rates of weight gain with PGI_2, either alone versus control or with STA_2 versus STA_2 alone, were increased despite smaller increases in Pc. Taken together, these findings suggest that, in addition to increasing vascular permeability, PGI_2 increases vascular surface area as well.

Selective loss of red blood cells from the perfusate could lead to an overestimation of σ, and indeed we noted a diffuse hemorrhagic edema in lungs treated with PGI_2. It is unlikely, however, that this condition led to an underestimation of permeability with PGI_2 since the efflux of red blood cells should have been accompanied by a proportionate movement of fluid and proteins.

The pulmonary hypertension induced by STA_2 in isolated non–blood-perfused lamb lungs is primarily the result of pulmonary venoconstriction.[3] The present study demonstrates that the pulmonary pressor response to STA_2 in blood-perfused lungs is greater than that observed with a non–blood-perfused system. Although we found a significant increase in Pc by STA_2 injection, suggesting venoconstriction, the elevation of the Ppa was due mainly to vasoconstriction upstream from Pc (Figure 2). These results may be due to differences in the perfusates, since a variety of mediators derived from white blood cells or platelets may contribute to these pressor effects.

Garcia-Szabo et al[20] demonstrated that a selective inhibitor of thromboxane synthesis prevented the thrombin-induced increases in pulmonary lymph flow and the lymph protein clearance in intact sheep, suggesting that TxA_2 contributes to the increase in lung vascular permeability after thrombin infusion. However, while administration of arachidonic acid produced pulmonary venoconstriction associated with TxA_2 production in lungs, the microvascular permeability was not increased.[21–23] Our study demonstrated that STA_2 injection causes an increase in Kf, a similar rate of lung weight gain during hydrostatic stress despite a smaller elevation of Pc, and a decreased σ as compared with control lungs, suggesting that TxA_2 may also increase pulmonary microvascular permeability in isolated newborn lamb lungs. The disparity in these results may be due to differences in 1) the manner in which pulmonary edema was produced, 2) the parameters used to assess pulmonary vascular permeability, 3) species, and 4) age. Indeed, hypoxia has been shown to adversely affect lung fluid balance in newborn, but not adult, sheep.[24]

Consistent with the observations made by others in isolated adult lungs,[25,26] we noted that PGI_2 (either with or without STA_2) produced a greater rate of lung weight gain in spite of a smaller increase in Pc induced by the hydrostatic stress, and a decrease in σ. However, Gunther et al[27] and Ogletree[28] reported that PGI_2 did not alter the pulmonary vascular permeability in intact or unanesthetized sheep, and Demling et al[29] showed that the lung injury caused by endotoxemia was prevented by PGI_2. These observations suggest that PGI_2 contributes to the increased microvascular permeability to protein in isolated perfused lungs, but not in intact animals. Since the adverse effects

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of PGI_2 were also observed in non–blood-perfused lungs,[3] the permeability increase may be independent of the presence of platelets.

The increase in vascular permeability to protein associated with elevation of outflow pressure has been attributed to the "stretched pore phenomenon."[30] However, this phenomenon may not occur with every elevation of microvascular pressure,[31] or may require either very high distending pressures[32] or an inappropriate arterial relaxation resulting in greater transmission of pressure to the capillary bed. In control lungs we observed that a moderate increase in outflow pressure did not result in an increase in Kf from baseline, and was associated with a normal value of σ.[5] In a preliminary report, Ehrhart et al[33] have also shown that σ remained unchanged at venous pressures as high as 77 mm Hg in isolated dog lung lobes. In contrast, Rippe et al[34] demonstrated that Kf was increased when Pla exceeded 41 mm Hg in isolated dog lungs; however, papaverine (1.3×10^{-4} to 2.7×10^{-4} M) was used to produce maximal vasodilation and surface area. Maron and Pilati[35] also found that venous pressures elevated to only 18 mm Hg reduced the value of σ in lobes exposed to 10^{-3} M papaverine. It is possible that vasodilation by papaverine or PGI_2 coupled with increased capillary hydrostatic pressure augments the stretched pore phenomenon.

In conclusion, the administration of STA_2 and/or PGI_2 to blood-perfused isolated newborn lamb lungs resulted in an increase in the fluid filtration coefficient and a decrease in the osmotic reflection coefficient. Our findings suggest that both TxA_2 and PGI_2 increase pulmonary microvascular permeability to protein, and that PGI_2 additionally results in a greater amount of fluid filtration.

Acknowledgments

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